Joana da Silva Campinho

Licenciada em Ciências da Nutrição

The Influence of Music on the Perception of Taste

Dissertação para obtenção do Grau de Mestre em Ciências Gastronómicas

Orientadora: Professora Doutora Paulina Mata, Faculdade de Ciências e Tecnologia – UNL

Júri:

Presidente: Professora Doutora Isabel Coutinho Medeiros Dias, Professora Auxiliar, Faculdade de Ciências e Tecnologia - UNL

Arguente: Professor Doutor Paulo Henrique Machado de Sousa, Professor Adjunto, Universidade Federal do Ceará (UFC)

Vogal: Professora Doutora Paulina Mata, Professora Auxiliar, Faculdade de Ciências e Tecnologia - UNL

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AGRADECIMENTOS

À Professora Paulina, por tudo. Por me ter acompanhado desde o primeiro dia desta viagem que foi o mestrado. Por toda a aprendizagem e partilha de conhecimento, de experiências e vivências que marcaram estes dois anos. Por me ter ajudado a sonhar e a concretizar esta tese, com um apoio, carinho, disponibilidade e dedicação incondicionais, sem os quais não teria sido possível. Pela confiança que depositou em mim. Pela sua capacidade de alargar horizontes e ir mais além. Porque a paixão que a move é inspiradora.

Ao Professor Paulo Sousa, por toda a amabilidade, disponibilidade e apoio na definição da metodologia e tratamento estatístico dos resultados.

Ao Bruno Moreira Leite, por tão prontamente ter cedido a receita da incrível sobremesa que fez parte deste estudo e por toda a sua disponibilidade e apoio no tratamento estatístico.

Ao Tiago André Pereira, pelo excelente músico e pessoa que é. Pela amizade, dedicação e ajuda na seleção das músicas.

A todas as pessoas que tão solicitamente participaram no grupo de foco, na sessão de simulação e nas provas sensoriais propriamente ditas, ajudando a tornar isto possível.

Ao Bruno Campos e à Florina, que não tiveram mãos a medir no tempo, disponibilidade e carinho com que me ajudaram em toda a preparação e nas provas sensoriais. Existem poucas pessoas com um coração tão generoso como o deles.

Ao Rui, à Raquel, à Ana e ao Samuel porque a amizade deles foi das melhores coisas que Lisboa me trouxe. Em especial ao Rui e à Raquel, por terem estado sempre presentes, pelo carinho imenso. Pela certeza de que onde quer que a vida nos leve, nos abraços apertados deles cabe o meu mundo inteiro.

Aos colegas de mestrado, por todos os momentos vividos ao longo destes dois anos tão felizes, por toda a partilha de saberes e de sabores, marcados por experiências gastronómicas memoráveis. Aos professores que partilharam connosco todo o seu conhecimento e que nos ajudaram a crescer nesta descoberta.

A cada um dos meus amigos, por terem acompanhado com carinho todos os desafios que fui abraçando, todas as metamorfoses que me conduziram a este delicioso ‘aqui’. Em particular à Catarina, pelos longos anos de uma amizade tão especial. Por ajudar a tornar a vida mais leve em todos os momentos, principalmente nestes, com um carinho, apoio e força que fizeram e farão sempre a diferença. E ao Zé, *brother in law,* por já o ser no coração antes de o ser na ‘lei’. Pela amizade imensa, o apoio e a motivação tão importantes para mim, especialmente nesta fase.

À minha família, por ser o meu porto seguro nesta e em todas as viagens. Por um amor que não cabe em palavras. Aos meus pais, por a cada dia darem o melhor deles para que eu possa ser o melhor de mim. Pela presença, apoio e amor incondicionais. À minha irmã Inês, que eu acompanho desde o primeiro dia, pelo privilégio que tem sido vê-la crescer. Pela alegria, doçura e carinho que me enchem o coração, sempre. À minha irmã Bela, que me acompanha a mim desde o primeiro dia, pela cumplicidade imensa, pela presença carinhosa e pela partilha tão íntima do que somos. Por acalmar os meus medos e por acreditar em mim, sempre. Por toda a ajuda, o apoio e a força, sem os quais não teria conseguido.

A todas as sint(f)onias do universo.

"*What is 'real'? How do you define 'real'? If you are talking about what you can feel, what you can smell, what you can taste and see then 'real' is simply electrical signals interpreted by your brain*." (Morpheus in *The Matrix*)

ABSTRACT

The food experience is one of the most multisensory experiences. The background soundscapes, and particularly music, can influence not only behaviour and choices, but also the sensory perception, either discriminative or hedonic, of a food experience. The auditory properties of a musical piece could be matched in a congruent manner with the basic tastes, affecting the way consumers perceive, respond and remember the sensory attributes and the overall experience. Based on this premise, the present study was developed in order to extend the understanding of crossmodal interactions between gustatory and auditory stimuli. Concretely, it was intended to investigate the influence of background music on the tasting experience, namely on basic tastes and texture perception.

For this purpose, two musical pieces were selected to match with sweet and sour basic tastes, taking into consideration their auditory characteristics. The gustatory stimulus chosen was a dessert (passion fruit mousse) with these two basic tastes.

The sensory tests were performed immediately after basic tastes recognition tests and familiarization with the scale. Each participant experienced three different conditions, in different orders: *i)* control, where the dessert was tasted in silence; *ii)* experience A, where participants tasted the same dessert while listening a *sweet* musical piece that expectably would enhance sweet taste of it and *iii)* experience B, where participants tasted the same dessert while listening a *sour* musical piece that expectably would enhance sour taste of it.

The results show that the same dessert was not perceived exactly in the same way when participants were exposed to different music stimulus, what can corroborate by itself the music's influence on tasting experience. Moreover, it was verified that crossmodal correspondences between music and taste were stronger regarding sour taste where a significant effect was observed. Sweet music, by contrast, did not enhance the sweet taste of the dessert. However, it decreased the intensity of sour taste in the dessert what could suggest a different approach to crossmodal correspondences between music and taste.

These findings can be very helpful on design and building of new multisensory gastronomic experiences, applied by food businesses and restaurant entrepreneurs to enhance consumers' experience.

Key Words: Gastrophysics; Multisensory experience; Crossmodal correspondences; Perception; Music; Taste.

RESUMO

A experiência alimentar é uma das mais multissensoriais. A paisagem sonora, em especial a música, pode influenciar não só o comportamento e as escolhas alimentares, mas também a perceção sensorial, quer discriminativa quer hedónica, da experiência alimentar. As propriedades auditivas de uma música poderão ser ligadas de uma forma congruente aos gostos básicos, afetando a forma como os consumidores percecionam, respondem e lembram os atributos sensoriais e a experiência no geral. Com base nesta premissa, o presente estudo foi desenvolvido para ampliar a compreensão das interações modais cruzadas entre estímulos auditivos e gustativos. Concretamente, pretendia-se investigar a influência da música ambiente na perceção da experiência alimentar, nomeadamente nos gostos básicos e na textura.

Com este propósito, foram escolhidas duas músicas correspondentes ao doce e ao ácido, tendo em conta as suas características auditivas. O estímulo alimentar escolhido foi uma sobremesa (mousse de maracujá) com esses dois gostos básicos.

Os testes sensoriais foram realizados imediatamente após os testes de reconhecimento dos gostos básicos e de familiarização com a escala. Cada participante experienciou a sobremesa em três condições distintas, com diferentes ordens: *i)* controlo, onde a sobremesa foi provada em silêncio; *ii)* experiência A, onde os participantes provaram a sobremesa ao som de uma música 'doce', esperando-se uma intensificação do seu gosto doce; *iii)* experiência B, onde os participantes provaram a sobremesa ao som de uma música 'ácida', esperando-se uma intensificação do seu gosto ácido.

Os resultados mostraram que os participantes percecionaram a mesma sobremesa de forma diferente quando expostos a diferentes estímulos musicais, o que confirma, por si só, a influência da música na perceção da experiência alimentar. Adicionalmente, verificou-se que as correspondências modais cruzadas entre a música e o gosto foram mais fortes relativamente ao gosto ácido, onde se observou um efeito estatisticamente significativo. A música doce, pelo contrário, não intensificou o gosto doce da sobremesa. No entanto, teve efeito na diminuição da intensidade do gosto ácido da sobremesa, o que sugere uma diferente abordagem para estas correspondências modais cruzadas.

Estes resultados podem ter um grande potencial na criação e desenvolvimento de novas experiências gastronómicas multissensoriais, com aplicação quer por indústrias alimentares, quer por restaurantes, de forma a melhorar a experiência dos consumidores.

Palavras Chave: Gastrofísica; Experiência Multissensorial; Correspondências modais cruzadas; Perceção; Música; Gosto.

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1. INTRODUCTION

The definition of art is not a statement. Which fields exactly fit in still remains a topic of philosophic discussion. It is consensual that music is art. Painting and dancing is art. Poetry is art. Theatre is art as well. To raise culinary arts among these fine arts it is a matter of discussion and sometimes divergence (Hopia & Ihanus, 2014). However, food is one of the few things that can stimulate all our senses, and increasingly cuisine is moving from a traditional mean of providing nutrition to a mean of artistic expression (Hopia & Ihanus, 2014; Spence, 2017; Spence & Piqueras-Fiszman, 2014). In this "theatre of senses", a chef can be an artist who awakes emotion, tells stories and embraces diners in an astounding and sometimes surprising journey of feelings as any form of art can do (Spence, 2017).

Besides, food has a great potential to harmoniously dialogue with other forms of art, allowing to create multisensory experiences able to blow diners' mind. Lately, people are moving toward the *Gesamtkunstwerk,* a term commonly associated with the German composer Wagner as a way to integrate different forms of artistic expression in a unique masterpiece. Thus, food can be considered as a complete work of art, an experience that engages all the senses. In fact, it is hard to find how this purpose of creating a work of art capable to stimulate all senses could be reached without involving food or drink (Spence, 2017).

This paradigm change happened with the understanding that the eating experience is a matter of perception. Actually, the pleasure of eating does not reside in the mouth - as it could be wrongly implied - but in the mind. It is about the interpretation work of the mind of all sensory cues that are transmitted by food and the environment when eating (McGee, 2016; Shepherd, 2011; Spence & Piqueras-Fiszman, 2014). As referred by chef Heston Blumenthal: "*It is the conversation between our brain and our gut, mediated by our heart"* (Spence, 2017). The way food is perceived, in its wholeness, allied with the consumers sensitivity, associations, memories, emotions and feelings, will determine the final tasting experience and, consequently, how pleasant and memorable it can be (Shepherd, 2011; Spence & Piqueras-Fiszman, 2014).

On this regard, more and more food scientists and chefs are working together in order to better comprehend the flavour perception and provide a solid background for new creations. Using a scientific approach to measure and assess how people perceive and response to food, and how the senses can influence each other, will help to develop tools to play with them to highlight and enhance some specific aspects of the tasting experience. This will promote the overall pleasurable nature of food and the "all the experience" as an '*eatertainmen*t' (Spence, 2017).

Music is an art that markedly takes part in our daily life and has the power to change emotions and to make memories alive (Hopia & Ihanus, 2014; Kantono et al., 2016; Spence & Piqueras-Fiszman, 2014). People incorporate music, even unconsciously, in several activities to improve their overall enjoyment. The fact is that many times there is a general unawareness of the real impact that music exerts on the way the surroundings are perceived and felt. One of the few clear examples where the sound's impact is more noticeable is the films soundtracks. Undoubtedly music can hugely affect the whole experience of a film, triggering emotions and driving attention. These is why soundtrack composers carefully create musical pieces that best evoke and match with the feeling that each moment demands in order to improve the experience.

Music has the same role in the eating experience, however people in general are not so aware and, as result, do not look for an appropriate match that could rise the food experience into a new level (Hopia & Ihanus, 2014).

Apart the other senses, which could be considered as apparently more obvious in their impacts, researchers are keen to focus their studies into the effect of soundscapes and music in tasting experience and food behaviours (Knöferle & Spence, 2012; Spence, 2012a).

The present study tries to narrow the dialogue between music and food, taking into consideration the crossmodal correspondences between auditory and gustatory properties and the possible mechanisms underlying consumers' responses.

For the purpose of investigating the influence of background music on the tasting experience, a sensory analysis was performed for which a food stimulus was tasted in different moments, hearing different background music. Two musical pieces were chosen, each one with auditory properties congruent with one of the basic tastes present in the food stimulus.

For a better contextualization, this dissertation starts with a literature review regarding the food experience in general. In this section the multisensory nature of eating and the perception as key factor to flavour construction in the mind are explored. Then, the soundscape and music as a modeller variable of food experience are considered. An overview of the main studies developed in this area and the possible mechanisms that could be on base of the gustatory and auditory correspondences is presented. These findings were ground for this study. Chapter 3 describes the aims and hypothesis of the study as well as the materials and methodology used. Concretely, the food and musical stimuli, the participants' selection, the instruments used and the procedures and characteristics of sensory analysis tests are described. In chapter 4 the results are shown and discussed. The weakness and limitations of the study are also highlighted, with suggestions of improvements that could be taken into account in future studies. Lastly, a conclusion of the study is presented, encompassing the main findings and its potential on the design and building of new multisensory gastronomic experiences and on changing the food paradigm.

2. LITERATURE REVIEW

2.1. Multisensory experience

2.1.1. The science behind the art

The perception of the world involves the information of all senses: taste, smell, touch, sight and hearing, and its integration. These senses do not act in an isolated way, but rather interact with each other in order to provide a coherent awareness and meaning of the surroundings (Shepherd, 2011; Spence, 2017).

Eating is one of the most multisensory experiences. Even unconsciously, various sensory inputs that influence food choices and tasting perception are continuously received and processed (Auvray & Spence, 2008; Spence, 2013, 2017; Spence & Piqueras-Fiszman, 2014). The instantaneous decision for a wine instead of another, is the result of a perception and integration of the colour and viscosity of wine, the shape of glass or even the sound of wine being poured. All these sensory cues when received and integrated determine subsequent action (Hopia & Ihanus, 2014). Even after a choice, and while drinking, senses still provide information regarding the taste, the aroma and the astringency. All the food experience is a pleasurable flow of senses where it is hard to understand when a perception starts and another disappears. On this regard, food perception is created with combined effort of several senses (Hopia & Ihanus, 2014; Shepherd, 2011; Spence, 2017).

Although gastronomy has always had an important presence in peoples' lives, the growing awareness of the eating experience as multisensory is relatively recent. This paradigm change emerged in part as a consequence of a deeper knowledge about the way brain perceives and integrates the information given by the different senses (Spence, 2013, 2017; Spence & Piqueras-Fiszman, 2014). A focus on the sensory and emotional elements of a food experience, and the better understanding of the mechanisms underlying the way flavour[1] is built in the mind, provides insightful findings which can have a practical repercussion into the creation of eating experiences (Spence & Piqueras-Fiszman, 2014).

Some advances already achieved in this field started with the neurogastronomy science, which can be defined as the study of the complex brain processes involved in flavour construction, regarding eating or drinking experiences (Shepherd, 2011; Spence, 2017; Spence & Piqueras-Fiszman, 2014). This science has been crucial for a better comprehension of the organization and responsiveness of the brain itself, as well as the role of food as strong modulator in this

[1] According the International Organization of Standardization *flavour* can be defined as a "complex combination of the olfactory, gustatory and trigeminal sensations perceived during tasting". And it may be influenced by tactile, thermal, painful and/or *kinaesthesic* effects (for Standardization, 2008).

process. Neuroscientists hope to found common parameters in the sensory perception paths in the brain and an integration that could be used across individuals (Shepherd, 2011; Spence & Piqueras-Fiszman, 2014).

Although neurogastronomy has been a valuable ground for the understanding of the flavour in brain, its achievements represent just a part of the science behind the eating experience (Spence & Piqueras-Fiszman, 2014).

There are many influencing factors in the way food and drink are experienced. In fact, it is hard to find a straight explanation for the fact that a food experience has certain characteristics for one person and their perception can be hugely different across individuals. Besides sensory perception, there are many other subjective factors such as emotions, feelings and memories, playing an important role in an eating experience (Shepherd, 2011; Spence, 2017). Neither neurogastronomy, modernist cuisine - which focus on food and its preparation - nor even sensory science and the study of how people perceive sensory attributes of certain food, could separately give answers to all these questions related to food experience.

Thus, it was necessary another approach, that would take in consideration all findings, materials and resources from these sciences, in order to better understand the eating experience and all its possible influencing factors (Spence, 2017).

From this need emerged a new science, *gastrophysics*, which combine neurogastronomy, sensory sciences, experimental psychology, cognitive neurosciences, design, marketing and behavioural economics (Spence, 2017). Gastrophysics provides a solid support for the assessment and measurement of all factors - both internal or external to food and drink itself - that can exert an impact on multisensory dining experience, using a diverse range of tools, techniques and ways of thinking in people's response (Spence & Piqueras-Fiszman, 2014). The name itself is a merge between "*gastronomy*" – reinforcing the role of the culinary arts as an inspiration and a starting point- and "*psychophysics*" – highlighting the role of the scientific study of perception (Spence, 2017).

It is not a surprise anymore that the content of a plate is just a part of the overall food experience. There is a general awareness that food tastes markedly different depending on the environment: the place where someone is eating or drinking, or even the people with whom the experience is shared. Thus, it is a concern, not only for food scientists, but also for food experience delivers, from restaurants to food companies, to explore the science behind the art in order to develop new and memorable food experience (Spence & Piqueras-Fiszman, 2014).

The applications of this knowledge are endless and its extent could go, for example, from transforming a meal in an emotional journey, to the transformations of food in healthier one using these perceptions 'tricks' to avoid compromise on taste (Spence, 2017). With these studies it could be possible to create better experiences just by adding gastrophysics findings and psychological "illusions".

2.1.2. Food experience

Eating is an experience. It is more than the meal itself. If the food experience was not multisensory, one might argue that it could be a contained event. But the truth is that although the meal itself will only take some amount of time, depending on the experience it can last a lifetime as a memory (Spence, 2017).

Some factors that have been proved to be influencers in memories making processes are surprise, amount of concentration needed and combined sensations. This is applied to any experience, and has an important role in the eating one. Thus, the food experiences that take more advantages of its multisensory nature, will require a deeper processing in order to be understood, and as result will be better recollected as memories (Spence, 2017).

Currently, people are more willing to pay and focus in collecting experiences. This fact is changing the consumer market, as people do not want to buy the product specifically, or the meal itself, but the whole experience that comes from it. To achieve that purpose it is imperative to direct the focus on food as a multisensory experience and be aware of the role of the '*everything else'* (Spence, 2017; Spence & Piqueras-Fiszman, 2014).

2.1.2.1. Perception of food and the 'everything else'

Several *gastrophysics* studies aim to understand the role of other factors in the food experience, externals to food itself. It was found that people rate the same food and drink differently depending on the colour of the plate, the cutlery, the environment lighting, the music, and so on (Spence, 2017).

More than that, these factors affected not only the way of people perceived sensory-discriminative qualities (e.g. what was the meal presented, what was tastes of and how intense was the flavour) but also hedonic responses (e.g. how much people found the experience pleasant or not) (Spence & Piqueras-Fiszman, 2014).

Although the food itself play a crucial role on how people perceive the eating experience, these findings suggest that the other factors play an equal role in the way people perceive, react and remember the food experience. Charles Spence even go further suggesting that half of the food and drink experience appear as a result of the "*everything else*" (Charles Spence, 2017). Adding the food perception itself, senses impact on the perceived pleasantness of the overall experience. The emotions triggered by the eating experience are an important issue that needs to be considered (Spence, 2017; Spence & Piqueras-Fiszman, 2014).

All the complex set of factors involved in and eating experience can be considered and used to enrich the experience. Studies have shown that when a congruence between atmosphere and the food served is created, people perceived the experience as more pleasant. Atmosphere also has an impact on food behaviour, affecting decisions as: where and what one eats, the time spent eating the dish and the perceived overall experience (Calvert & Thesen, 2004; Spence &

Piqueras-Fiszman, 2014). One of the *gastrophysics* big question is: “how changing the environment really affects the way people perceive their food/drink?” (Spence, 2017). Furthermore, “how this knowledge can be used to enhance the eating experience, ensuring that it actually appears at its best?”. With the growing body of researches in this field, it will be possible to play with senses, improving and optimizing the experience by the correct choice of of the “*everything else*” (Spence, 2017; Spence & Piqueras-Fiszman, 2014).

2.1.3. Flavour is in the mind

Every food experience, even the simplest one, as biting a peach, counts on complex multisensory interactions. The brain must integrate all sensory inputs, binding together the aromatic smell, the taste, the texture, the appearance, colour and shape, the sound of each biting or even the tactile sensation on the hands and mouth. All these sensory cues have a huge impact in the way in which the idea of the peach appears in one’s mind, and their combination with memories, will define the flavour itself for that person (Hopia & Ihanus, 2014; Shepherd, 2011).

A usual misconception is that flavour is in the foodstuff. Actually, flavour is a perception, an experience that is constructed in the mind. The molecules that compose food do not contain by themselves any sensory quality. However, the experience of food is sensory and taste, smell, texture, colours, sounds are perceived, although the chemical and physical materials that generate these sensations do not have those qualities (McGee, 2016; Shepherd, 2011).

For instance, the sensory quality of sweetness is a result of a message sent from receptors in the tongue to the brain when molecules of sugars are present in foodstuff that is being eaten. The brain translates that message into a sensation of sweetness. Chemically food has sugar, but the sensory experience of it is a result of the brain's construction triggered by sensors’ activation (Hopia & Ihanus, 2014; McGee, 2016; Shepherd, 2011). From this, it can be concluded that, when exposed to exactly the same foodstuff, with a specific and measurable combination of molecules and physical materials, the individual perception of several individuals could be completely different from each other. Another proof of the brain’s role in the flavour construction are the changes in flavour perception resulting from physiological damages in brain regions that decode the sensory cues or even in the transmission system from the sensory receptors into the brain. As result, people cannot perceive the attributes that compose the flavour.

Certain molecules in food activate the chemical senses, such as taste and smell. By contrast, touch, sight and hearing senses are categorized as physical senses and they are activated, not by specific chemical compounds, but by food appearance (Hopia & Ihanus, 2014; Shepherd, 2011).

There are particular differences between the chemical senses, however, their mechanism is similar: molecules in food activate the receptor cell or cells in the body, and those transmit that information, as impulses, through taste and smell nerves, into the brain, allowing their identification and processing (Hopia & Ihanus, 2014; Shepherd, 2011; Spence, 2013).

The sense of taste is activated when the chemical molecules of taste interact with receptors in the tongue, allowing to detect five basic taste sensation: sweet, sour, salty, bitter and umami. Regarding the sense of smell, there are different volatile molecules (aromas) that interact with olfactory receptors in nasal cavity. These molecules can reach the receptors through two different paths: orthonasally, by inhalation of odour molecules through nostril, or retronasally when odour molecules reach the olfactory bulb through the mouth as result of its release on chewing process. Thus, when people have a cold, these molecules cannot easily reach the olfactory bulb in the nose, compromising the aroma perception (Hopia & Ihanus, 2014).

Regarding touch perception, there are an integration of several sensations: *1)* touch receptors on the skin, fingers, lips and mouth that are responsible for the tactile perception; *2)* receptors that respond only to pain; *3)* the thermoreceptors, that only initiate an impulse when activated by heat or cold. These reactions to touch, pain and temperature allow the perception of the food texture determined by food structure and the mouth feeling. (Hopia & Ihanus, 2014; Shepherd, 2011).

For the sight perception the eyes have two kinds of photoreceptors, rods and cones that are activated by the light density and electromagnetic radiation. These allow to identify the food colour, the size, shape and quantity of the food (Hopia & Ihanus, 2014; Shepherd, 2011).

Finally, the sense of hearing confers the ability to interpret either the sounds of food or those of the surrounding atmosphere. This perception is achieved by changes of pressure as result of the sound waves and vibration of the air or bone conduction in the case of the chewing process (Hopia & Ihanus, 2014; Shepherd, 2011).

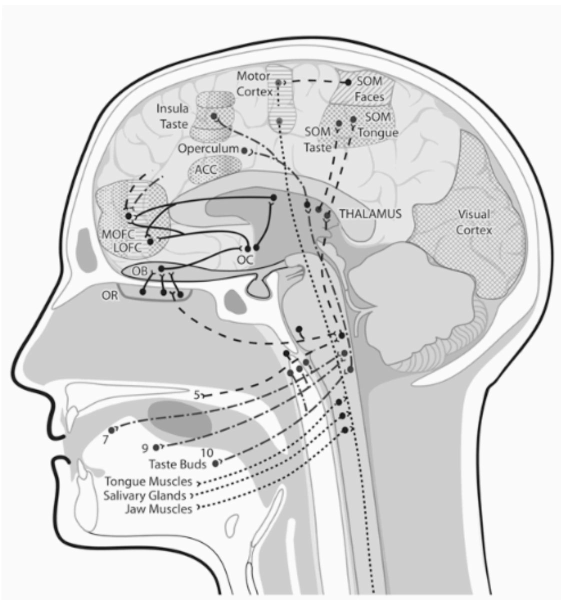

Figure 2.1 The human brain flavour system (Shepherd, 2011)

Perception of food results from a combination of all senses, being probably the flavour one of the most multisensory experiences experienced. However, the smell sense is the one that plays the main role, and combined with taste and oral- somatosensory cues provide the traditional definitions of flavour. Although these definitions do not include auditory and visual sensory cues as part of flavour perception, a growing body of recent studies, as the present one, are trying to evaluate the role played by these senses in flavour perception (Hopia & Ihanus, 2014; Shepherd, 2011) .

2.1.3.1. Flavour perception and action systems

The human brain flavour system it is composed by two stages. The first one is the sensory system that convert the individual sensory representations into the combined sense of flavour. This perception of flavour count on the multisensory integration already referred. When several stimuli from different sensory modalities are received at the same time, the brain cells, in a certain region, associate theses stimulus in a combined response that is stronger than the sum of the individual responses (Shepherd, 2011).

The second stage is the action system that embraces the whole ability of the human brain systems to respond to the flavour perception and affect behaviour. Here, the emotion, memory and language have a great impact on one's responses (Shepherd, 2011).

Thus, the human flavour system counts with a networking of regions and connections beside the senses mechanisms that are used to give meaning to the flavour.
Both systems point to a new concept of a human brain flavour system which can be considered one of the more extensive in the brain, as it uses and creates perceptions, emotions, language, memories and decisions based on flavour (Shepherd, 2011).

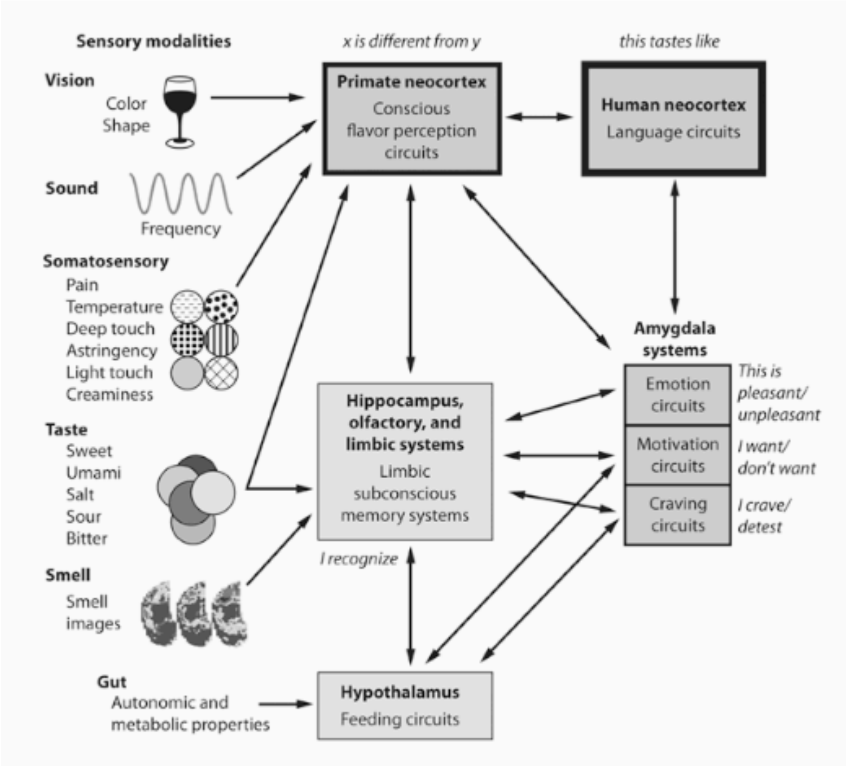

Figure 2.2 Human flavour systems. The left side represented both sensory systems and the right side associate behaviours with the parts of the brain that mediate them (Shepherd, 2011)

2.1.4. Multimodal and Crossmodal Correspondences

The knowledge that brain integrates the information and processes the different senses as a whole, also changed the way research is made. Previously, scientists thought that visual stimuli were processed by visual brain, sounds heard by auditory brain, and so on, unaware of the links and relation between the senses (Spence, 2017).

However, contrasting with this way of thinking, food experience perception cannot be considered as several individual experiences appearing at the same time, but rather one unified experience that results from the coordinated operation of more than one sensory modality (Auvray & Spence, 2008). This type of multisensory experience may be defined as *multimodal*. However, it has characteristics that go beyond the typical multimodal experience, it can be a *crossmodal* experience. This results from the fact that the operation of one sensory modality can influence and alter the operations of the other senses. In other words, changing what people experience in one modality can sometimes change their perception of the stimuli presented by another (Spence, 2011). To better understand the extent of influences between different sensory dimensions, several empirical crossmodal studies have been conducted, showing a strong coherence between them (Calvert & Thesen, 2004; Driver & Spence, 2000).

While in a crossmodal approach the study focus on a specific sensory modality and its influence on another modality, a general multisensory approach uses various senses and change the environment in order to affect the multisensory integration in the brain.

Over the last decade, gastrophysics has developed a profound knowledge of how changes in some senses stimuli can affect the food perception. More than that, some key rules were proposed about how brain combines information - as *superadditivity* (where a combination of various stimuli results in a stronger multisensory effect) (Spence, 2017), *subadditivity* (where a combination of various stimuli results in a weaker multisensory effect) (Stein, Stanford, & Rowland, 2014) and *sensory dominance* (when more than one sense are stimulated simultaneously and the stimuli of one of these senses overlap to the stimuli of the other) (Colavita, 1974).

Two of these studies, conducted in different sensory events, are described in the next paragraphs.

2.1.4.1. "*The singleton sensorium*"

In this study (Velasco, Jones, King, & Spence, 2013) three rooms were prepared for the experience of tasting the same whisky, having each one a different environment. One room pretended to recreate a British summer afternoon, another was focused in evoking sweetness and the last one had a woody environment. Each room had congruent atmospheric soundscape playing on background.

For the sweet room, every features were chosen, according to literature, in congruence with sweetness to enhance its perception: pinky-red colour (Spence, Levitan, U. Shankar, & Zampini, 2010), everything had round shapes (Velasco, Woods, Petit, Cheok, & Spence, 2016), a sweet-smell was created (using a non-food-related fragrance) and the high-pitched tinkling (Crisinel & Spence, 2009, 2010) of what sounded like wind chimes, coming from a ceiling-mounted loudspeaker (sound created for this study) (Velasco et al., 2013).

The British summer afternoon room was designed to enhance grassiness sensations on the nose. The 'woody' one wanted to enhance a textured finish, or aftertaste, in the mouth. The results were congruent with what was expected, as people rated whiskey significantly grassier in the British summer afternoon room, significantly sweeter in the sweet room and with a significantly woodier aftertaste in 'woody' room. In general, participants preferred the whisky in the 'woody' room (Velasco et al., 2013).

These experiments showed that affecting the multisensory environment in a congruent and superadditive manner resulted in a change of the perception of the food/drink (Spence, 2017; Velasco et al., 2013).

2.1.4.2. "The colour lab"

Another important study to mention is called "*The colour lab*" (Spence, Velasco, & Knoeferle, 2014). This was probably the biggest event of this kind. It counted with 3000 people and was incorporated in a festival. Each person received a black glass with Spanish Rioja. They tasted the wine in different conditions: with regular white lighting (as reference condition), under red illumination, under red illumination with "*sweet music*" and then green illumination with a "*sour music*". Participants were asked to rate the wine on taste, intensity and liking scales, regarding each condition. The results showed a change (15 to 20%) in participants' rating on switching an audiovisual atmospheric combination for another, emphasizing a superadditive effect. It was shown that the combined sensory cues had a bigger effect than would have individuality. Results showed that the combination of red lights and *sweet music* accentuated the fruitiness perception of wine, while the green colour and *sour music* highlighted its fresher notes (Spence, 2017; Spence et al., 2014).

Although not every person processes the senses in the same way, these studies reinforce the role of the senses, and its crossmodal interaction, in the eating and drinking experience, and show that people tend to process combinations of auditory and taste stimulus in similar ways. More than that, this knowledge opens doors for the design of events where senses are combined and explored as part of the experience (Spence & Piqueras-Fiszman, 2014).

2.2. Soundscapes and music

All senses have an important role in flavour perception. Sound is not usually recognized as a crucial element on the food experience, people are more aware of the role of other senses as the taste, the smell, the visual appearance and even the mouthfeel and oral texture. However, what is heard while eating, being the sounds of food or those of the environment, has a huge impact in food perception and experience (Spence, 2012a, 2015, 2017; Spence & Piqueras-Fiszman, 2014). In this chapter this '*forgotten flavour sense*' will be explored, focusing particularly the crossmodal interaction between music and taste.

2.2.1. Eating sounds and surrounding sounds, and its influence in food perception and eating behaviour

During consumption, several types of sounds can be directly related with food (e.g. the crispiness of chips or the fizziness of a beer) or with its packaging, or they can be indirectly associated (environment soundscape) (Spence, 2012a).

Food texture is highly related with its acceptance and enjoyment. Which might be less obvious is that many of these texture proprieties that were considered desirable and pleasurable - as, for example, being crispy, crackly, crunchy, carbonated or creamy – are, at least in part, the result of what is heard while eating (Spence, 2012a, 2017; Spence & Piqueras-Fiszman, 2014).

Sounds of food fracture in mouths, when it is being chewed or crushed between the teeth, provide significant information to the brain about the texture of the food being consumed

(Shepherd, 2011; Spence, 2017). Thus, specific sonic cues characteristics of noisy food (crispy or crunchy, for example) are appreciated as they are related to desirable features of the food items, meaning for example that they are fresh, new and probably seasonal (Spence, 2012a, 2017).

In general, the clearer and louder the sound, the more enjoyable it is the eating experience (Shepherd, 2011).Thus, it can be easily understood why there are an increasing number of chefs concerned about adding sonic elements to their dishes in order to make the diners' experience more pleasurable (Spence, 2017).

Liquids also have their characteristics sounds that influence the flavour perception. It can be the swished sound of a drink in the mouth or the specific '*glou-glou'* sound of the wine being swallowed. It can be even a characteristic sound of a drink in the glass, as the bubbles popping in a glass of champagne or the fizzing sound of a beer (Shepherd, 2011). For example it was showed that frequency of the sound had an effect on how pleasant the beer was perceived (Holt-Hansen, 1968, 1976). Even before ingesting, the characteristic sounds of a drink helps to set up the expectation, awaking the senses for what comes next (Spence, 2017; Spence & Piqueras-Fiszman, 2014).

Besides the eating sounds, the packaging sounds and kitchen & preparation sounds provide reliable cues about the next tasting experience (Hopia & Ihanus, 2014; Spence, 2017). Therefore, they are important to set up expectation (Spence, 2012a, 2017; Spence & Piqueras-Fiszman, 2014). The characteristic sound of a certain context can also completely alter the perception and enjoyment of a food experience (Spence, 2012a, 2017; Spence & Piqueras-Fiszman, 2014).

There is an iconic dish named "The Sound of Sea", which uses the influence of the environmental sounds related to a specific context to enhance the food experience perception. It resulted from experiments, conducted by Chef *Heston Blumenthal* and Professor *Charles Spence* at *The Fat Duck Restaurant*. Participants were invited to taste an oyster dish while listening either to the sound of the sea or the sounds of farmyard animals, and to rate its pleasantness in each situation. The results demonstrated that the oysters were rated significantly more enjoyable, but not saltier, while they were listening the sound of sea when compared to the farmyard sound (Spence, 2012a, 2013, 2017; Spence & Piqueras-Fiszman, 2014).

Figure 2.3 'The sound of sea' seafood dish, as served at Heston Blumenthal's The Fat Duck restaurant (Charles Spence, 2013)

In another experiment, participants tasted bacon-and-egg ice cream while listening either the sound of a sizzling bacon or the clucking of farmyard chickens. The results showed that participants rated the same bacon-and-egg ice cream significantly eggier when listening the clucking of farmyard chickens sound, but the bacon flavour became more intense when listening sizzling bacon (Spence, 2017).

These powerful findings showed that the stronger the congruence between the food and the natural sound of the context to which that food is related, the more enjoyable and pleasurable will be the tasting experience. Undoubtedly, sound can influence the emotional response to food in a multisensory environment, playing a remarkable role in the overall tasting experience perception. As Blumenthal referred: *“Sound is one of the ingredients that a chef has at his/her disposal”* (Spence & Piqueras-Fiszman, 2014). And it has been creatively included in some dishes of several chefs, emphasizing the multisensory nature of the experience (Spence, 2017).

Food choices, awareness of passage of time, consumer purchasing behaviour and overall perception of the service quality received can also be profoundly influenced by the background music on a store, restaurant or café (Spence, 2012a, 2017; Spence & Piqueras-Fiszman, 2014).

For instance, regarding the ethnicity of the background music, a study (Yeoh & North, 2010) where participants were invited to choose between Malaysian and Indian food while listening either Malaysian or Indian music playing on background, showed that they chose food in a congruent manner. Even in terms of food experience, it was shown that this ethnic congruency reinforces the perceived authenticity of the tasting experience, being the musical context an important variable (Carvalho et al., 2015).

Regarding music style, some researches (North & Hargreaves, 1998) shown that people in a student’s café were willing to pay more when classical music was played than when easy listening or pop music were played or no music at all.

The musical parameters as the *tempo* (beats per minute) and the *volume* of background music also were shown to exert influence in the speed of eating and drinking and how long people stayed in a given place. The faster (Milliman, 1986) and louder the music was, the more rapidly people ate (Spence, 2012a, 2017; Spence & Piqueras-Fiszman, 2014).

The overall pleasure regarding the background music can also have an impact in time spent in a given environment. The more unpleasant the music, the less time people spend in the place. By contrast, the more people like the music, the more time they spend there, and in a general way, the more they like the food or drink as well (Spence, 2012a, 2017).

It is important to bear in mind that both the absence of music and the presence of too much sound (music or background noise) can distract diners from food and drink enjoyment (Spence, 2017).

2.2.2. Soundscape and music and its influence in the perception of taste

A large body of research have shown the profound effect of background soundscapes and music, not only in food behaviour and choices - as mention before - but also in the perception of food sensory attributes and overall experience. All these findings are awaking people's interest on the matching of music/soundscape to specific tastes, flavours and food textures, in order to enhance the multisensory experience (Knöferle & Spence, 2012; Spence, 2011, 2012a; Spence & Piqueras-Fiszman, 2014).

Cross modal correspondences, as briefly mention before, can be defined as the people's ability of mapping with consistency apparently unrelated attributes or dimensions from stimuli (either physically or only imagined) of different sensory modalities (Spence, 2011).

One of the most studied crossmodal correspondence regarding auditory cues is between music and taste. As refer Bruno Mezs: "*There exist an ample overlapping between the set of body organs we use to speak, to sing and taste; This fact suggests the existence of a fertile ground for the emergence of correspondence between the linguist, musical and gustatory experimental domains*" (Hopia & Ihanus, 2014).

In fact, music and language evoke the production and interpretation of organized complex sound sequences. Language may share with music a privileged route into the mind as mediator and shaper of concepts (Mesz, Sigman, & Trevisan, 2012). Music and language can shape the meaning of a word and determine physiological indices of semantic processing (Mesz, Trevisan, & Sigman, 2011).

The idea that musical features can be described by gustatory qualities is not recent. Beyond the strictly acoustic level, some straight metaphor as a "*sour note*" or a "*sweet voice*" involve taste-sound correspondences. Furthermore, in musical vocabulary, taste-sound sensory metaphors can be found, as the use of the Italian term *dolce* (sweet) to designate soft, gentle and delicate playing (Knöferle & Spence, 2012; Mesz et al., 2012). Although very uncommon, other taste words appear as music indicators, for example "*âpre*" (bitter) in *La puerta del vino* of Debussy (Mesz et al., 2012). This example shows a low pitch register and a moderate dissonance (Mesz et al., 2012).

Zarlino, an important Renaissance music theorist of the XVI century, mentioned the minor consonances as 'sweet' (*dolci*) and 'soft' (*soavi*) (Mesz et al., 2011). Besides, some composers associated specific instruments with tastes. Berlioz was one of them, referring the 'small acid-sweet voice' of the oboe (Knöferle & Spence, 2012; Mesz et al., 2011).

Apart from such subjectivity and historical connection of sounds and tastes, in the last years, some researches have been conducted regarding crossmodal associations between audition and taste, involving both simple (e.g. pure tones, basic tastes) and complex (music, flavours) auditory and gustatory stimulus. The results have consistently showed a specific psychoacoustic and musical parameters correspondence with the different tastes/ flavours/ textures (Bronner, Frieler, Bruhn, Hirt, & Piper, 2012; Carvalho, Wang, van Ee, Persoone, & Spence, 2017; Crisinel et al., 2012; Crisinel & Spence, 2009, 2010, 2011; Crisinel & spence, 2010; Guetta & Loui, 2017;

Knoeferle, Woods, Käppler, & Spence, 2015; Knöferle & Spence, 2012; Kontukoski et al., 2015; Mesz et al., 2011).

The main relevant musical dimensions targets of these studies were: *pitch* - that could be considered the attribute of auditory sensation whereby the sound is organized in a scale going from the low to high, based on perception of the vibrations' frequency; *duration* - which could be defined as the length of time of a note; *articulation* – which correspond to the degree of continuity between successive notes (*legato* without breaks between notes and *staccato* where each note is separated from the others); *loudness*- which correspond to the sound's volume of improvisations; *degree of dissonance (*sometimes called *gradus)* - where dissonance sounds tend to be perceived as unpleasant or unstable whereas consonant sounds are usually associated with psychoacoustic pleasantness (Mesz et al., 2011) and *timbre* - which is the characteristic quality of sound that allows to distinguish different musical instrument or voices.

2.2.2.1. Crossmodal correspondence between sounds and tastes/flavours

In the first studies regarding the auditory cues (Holt-Hansen, 1968, 1976) participants were asked to match the pitch of a pure tone with two different types of beer. The results showed that the pitch chosen by participants varied regarding the beer presented, where the *Carlsberg's Elephant* evoked tones with an average frequency of 640-670 Hz, whereas the regular *Carlsberg* was matched to a tone with 510-520 Hz. Besides, the sensory experience was described as more pleasant when the pitch and taste were considered congruent (Holt-Hansen, 1968, 1976).

Still regarding pitch, in later researches Crisinel and Spence (2009) used the Implicit Association Test to assess the consistency of crossmodal correspondences between musical sounds' pitch (high *versus* low pitch) and sour *versus* bitter basic tastes (Crisinel & Spence, 2009), as well as sweet *versus* salty basic tastes (Crisinel & Spence, 2010). The results showed that high-pitched sounds were related with both sour and sweet tastes, whereas bitter taste were related with low-pitched sounds instead (Crisinel & Spence, 2009, 2010).

As they used food names rather than real food stimuli in these researches (Crisinel & Spence, 2009, 2010), it was not completely clear whether any matching of such (fictional) tastes might have been confounded with both linguistic features or specific phonetic qualities of the speech sounds present in the food names themselves (Simner, Cuskley, & Kirby, 2010). Thus, in order to overcome these concerns in a follow-up research (Crisinel & Spence, 2010) the above-mentioned experiment was replicated with real food stimuli instead the foodstuff names. Sweet and sour tastes were again reliably mapped to high-pitched sounds, bitter tastes to low-pitched sounds and salty tastes to medium-pitched sounds (Crisinel & Spence, 2010). Furthermore, this study highlighted crossmodal correspondences between basic tastes and different musical instruments sounds (that were only different in timbre). The results indicated that bitter and sour tastes were consistently mapped to trombone sounds (rated as rather unpleasant by participants), whereas sweet tastes were mapped to piano sounds (rated as rather pleasant by participants) (Crisinel & Spence, 2010).

The previous mentioned studies suggest a crossmodal correspondence between low-level psychoacoustic properties, namely pitch, and basic tastes (sweet, sour, salty and bitter). They were a valuable ground for more researches focused on more complex auditory and gustatory stimuli, such musical sequences and flavours (Knöferle & Spence, 2012).

2.2.2.2. Crossmodal correspondences between music and/or complex flavours

Crisinel and Spence (2011), in addition to their previous studies, described above, assessed crossmodal correspondences between flavoured milk solutions and instrument sounds (Crisinel & Spence, 2011). Consistently with the previous results, a significant effect of flavour on pitch and instrument type (piano, strings, woodwinds, and brass) choices were observed. These results also highlighted that sound-flavours crossmodal associations were present in more complex food stimuli, not being restricted to basic tastes and flavours exhibited individually (Crisinel & Spence, 2011).

Later (Crisinel et al., 2012) it was reported that people's perception of bittersweet toffee was altered by varying the pitch of the soundtrack they were listening while eating. The soundtracks had been developed on line with the previous studies that showed an association between low-pitched tones and bitter tastes, and that high pitched tones matched with sweetness. This experiment's results showed significant differences on sweetness and bitterness perception of toffee by participants, but not in the hedonic responses regarding flavour liking while listening to the different soundtracks (Crisinel et al., 2012).

In another research work (Crisinel & Spence, 2012) designed to evaluate whether pleasantness mediated crossmodal correspondences between different types of chocolate (milk, marzipan and dark) and sounds differing in their pitch and timbre (instrument type), Crisinel and Spence reported that while participants' choice of musical instrument could be predicted by the pleasantness rated for the different chocolates, the pitch choice was not (Crisinel & Spence, 2012).

Bonner and collaborators (Bronner et al., 2012) considered any crossmodal associations between music and flavours. In a first experiment, participants were asked to taste vanilla and citrus flavoured drinks and evaluated auditory associations with each of them, using a descriptive analysis. The vanilla flavour was related to a soft, dull timbre, neither sharp nor rough, a small range ambitus, a legato articulation, a non-syncopated rhythm, a melody with small step intervals, and a slow tempo. By contrast, a citrus flavour was related to a bright, sharp and rough timbre, a medium-high range ambitus, an accentuated staccato articulation, a syncopated rhythm, a melody with medium-large step intervals, and an energetic and fast tempo (Bronner et al., 2012). On the basis of these results, both shorter and longer musical pieces were composed to represented orange, lemon, grapefruit and vanilla flavours. The results suggested that participants were able to properly match musical pieces to flavours (Bronner et al., 2012). However, it was unclear whether their results might not be described as highlighting the musical parameters associated with sweetness and sourness instead, since they were obvious attributes of their flavours (Knöferle & Spence, 2012).

A study conducted by Knöferle and Spence (2012), demonstrated a systematic mapping between psychoacoustic and musical properties onto basic tastes. Controlling one auditory property of a short chord progression at a time (synthesized from pure tones), participants selected, on each trial, the sound that best corresponded to a given basic taste word (Knöferle & Spence, 2012).

First, the findings of this study reinforced the previously identified association between sweet tastes and higher pitch and bitter tastes and lower-pitched sounds (Crisinel & Spence, 2009, 2010). Sour and salty tastes fluctuated between sweet and bitter tastes in terms of their pitch height (Knöferle & Spence, 2012). Second, the results showed that people reliably mapped auditory roughness onto basic tastes. Generally, participants attributed the lowest roughness values for sweet taste words, significantly higher values for salty tastes, and even significantly higher values for sour and bitter tastes (Knöferle & Spence, 2012). Third, sweet tastes were associated with sounds low in discontinuity, whereas sour, salty, and bitter tastes were related with high-discontinuity sounds (Knöferle & Spence, 2012). Four, a significant difference was found for musical tempo, with sour tastes related with the highest average tempo and bitter taste linked to the lowest average tempo (Knöferle & Spence, 2012).

In another study (Mesz et al., 2011) investigated musical and verbal associations with the basic tastes (sweet, salty, bitter and sour), in order to understand whether taste words elicited consistent music representations. It was asked to trained musicians experts to improvise on the basis of these four taste words. These improvisations were mapped to five relevant musical dimensions: *pitch*, *duration*, *articulation*, *loudness*, *degree of dissonance*.

The results demonstrated that, even in free improvisation, taste words evoked very reliable and consistent musical patterns, where *sour* improvisations were high-pitched, fast, articulated, and dissonant; *bitter* improvisation were low-pitched and low articulated (*legato*), with some dissonant attributes; *salty* improvisations were medium-high-pitched, fast and high articulated (*staccato*) and *sweet* improvisations were medium-high-pitched, consonant, slow, soft, low articulated (*legato*) and low loudness (Mesz et al., 2011). It was also clear that music representations for each taste are themselves very different. In a subsequent experiment, the mapping of the perception of music to taste words was also investigated, where non-musical experts listened to a fraction of the improvisations from the first experiment. The results showed that participants classified with high accuracy the taste word which was on the basis of the improvisation (Mesz et al., 2011).

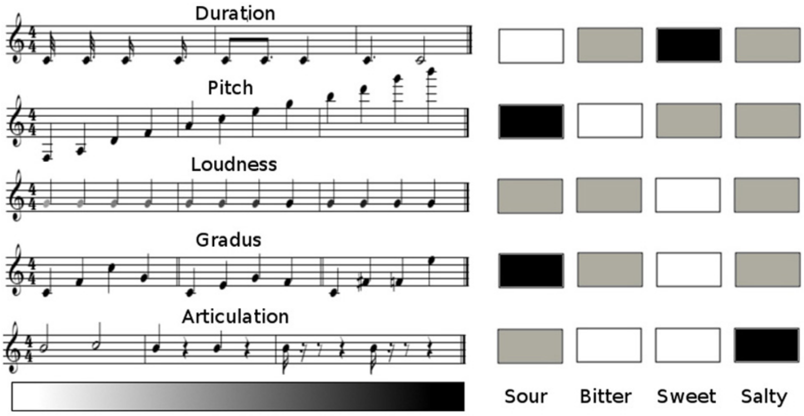

Figure 2.4 Matrix pattern of taste words regarding the musical parameters. Each bar score corresponds to a different musical parameter. From left to right there are a colour progressing: low (white), medium (grey) and high (black) values of each parameter. The scheme to right summarizes the taste words- musical parameters matching (Mesz et al., 2012)

A follow-up study (Mesz et al., 2012) demonstrated that musical pieces created on the basis of the identified taste profiles, using a computer algorithm were also reliably mapped to basic tastes (Mesz et al., 2012).

The combined results from these experiments suggested that associations between auditory and gustatory cues are bidirectional, such that auditory cues can be mapped onto gustatory qualities and vice versa (Mesz et al., 2011).

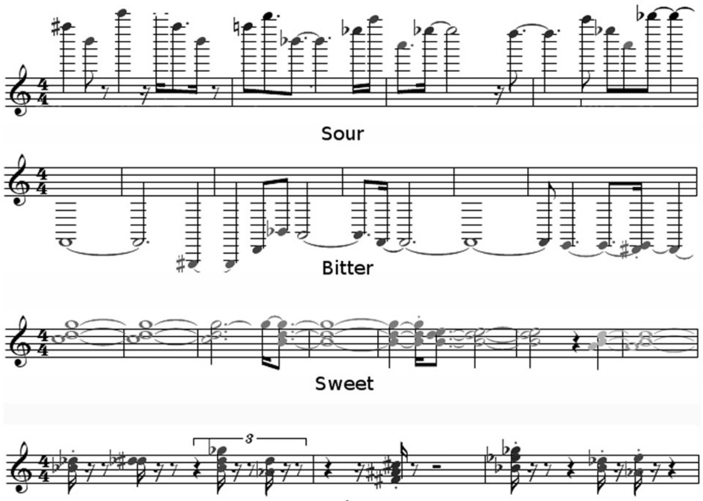

Figure 2.5 Typical music scores taken from improvisations on taste words. A few bars of piano improvisations' scores for representative examples of each taste-word. (Mesz et al., 2012)

It is worth to mention that in Mesz et al. (2011) study, besides the improvisation on taste words, the musicians were also asked to improvise on some emotion words generally used in music such as '*determined*', '*sorrowful*', '*ferocious*' and '*delicate*' ('*deciso*', '*dolente*', '*feroce*' and '*delicato*') which served as control words, as they are thought to elicit predictable responses. The results of these improvisations showed that in this case, the correspondence was not between musical attributes and taste qualities but between musical attributes and emotional concepts instead (Mesz et al., 2011).

Other study (Kontukoski et al., 2015), based on the previous findings, explored the musical influences on food-related words associations and food preparation. Sweet and sour related musics were selected or composed, and the participants were encouraged to performer three tasks. On the first one, it was asked them to freely generate food-related words that the music provoked in their minds. The results showed that sweet music generated words more linked to the word *sweet,* like for instance *chocolate* and *tasty.* By contrast, sour music produced words more connected to *sour*, like for example *fruits* and *sour* (Kontukoski et al., 2015). On the second one, participants could read food-word pairs, where each word was related with one of the basic tastes sweet or sour (for example, banana-lemon; chocolate-lingonberry). They were then asked to choose the two food words that better described the music they had heard. The results demonstrated that "sweet" music provoked sweeter taste association, where banana and chocolate were the preferred choice. In an opposite way, sour music elicited sour taste association, where lemon and lingonberry were the most chosen (Kontukoski et al., 2015). On the last one, participants were invited to freely choose the ingredients, among five juices and liquid honey, and prepare a drink congruent with the music they had heard. The results from the chemical analysis of the drinks reinforced the idea that the 'taste' of the music to which participants were exposed exerted an influence in participants' choices of ingredients for the drink mixture. This choice was congruent with music and taste association, since the sweet music generated drinks with higher sugar content, whereas sour music drinks with higher acidity (Kontukoski et al., 2015).

This study, besides emphasizing the strong music-taste words association, suggested also that music can influence the design and creation of culinary dishes (Kontukoski et al., 2015). In fact, this can be a reason for some chefs recommendation for listening a particular musical piece while cooking a certain recipe, aware about the impact that it can have in the final result (Hopia & Ihanus, 2014; Spence & Piqueras-Fiszman, 2014).

It is worth mention other study (Carvalho et al., 2017) where participants were asked to evaluated the perceived creaminess of the same chocolate samples (without knowing that they were identical) while listening two different contrasting soundtracks composed based on texture-correspondences. One of them was produced to match with creaminess and the other with roughness. The results showed that the 'creamy' soundtrack evoked the perceived creaminess and sweetness of chocolates as compared to the 'rough' soundtrack (Carvalho et al., 2017). Additionally, it was suggested that although participants preferred the 'creamy' soundtrack, this difference did not appear to impact their overall enjoyment of the chocolates (Carvalho et al., 2017).

Table 2.1 Summary of crossmodal correspondence between auditory and gustatory modalities referred in relevant researches. Adapted from Knöferle & Spence (2012).

Authors	Auditory Property	Sweet	Sour	Salty	Bitter
(Bronner et al., 2012)	Sharpness/spectral balance	Low	High		
	Roughness	Low	High		
	Ambitus	Small	Large		
	Articulation	Legato	Staccato		
	Rhythm	Non-syncopated	Syncopated		
	Melodic intervals	Small	Large		
	Melodic consonance	Consonant	Dissonant		
	Tempo	Slow	Fast		
(Crisinel & Spence, 2009)	Pitch		High		Low
(Crisinel & spence, 2010)	Pitch	High	High	Average	Low
	Instrument type	Piano	Brass	Brass	Brass
(Crisinel & Spence, 2010)	Pitch	High	High		
(Crisinel & Spence, 2012)	Pitch	High			Low
	Instrument type	Piano			
(Carvalho et al., 2017)	Roughness	Low			High
(Knöferle & Spence, 2012)	Pitch	High	Average	Average	Low
	Roughness	Low	High	Average	High
	Sharpness/spectral balance		High		Low
	Discontinuity	Low	High	High	High
	Speed		Fast		Slow
(Mesz et al., 2011)	Pitch	Average	High	Average	Low
	Articulation	Legato	Average	Staccato	Legato
	Speed	Slow	Fast		
	Loudness	Soft	Average	Average	Average
	Chord consonance	Consonant	Dissonant	Average	Average
	Melody consonance	Consonant	Dissonant	Average	Average

2.2.2.3. Possible mechanisms underlying crossmodal correspondences between auditory and gustatory stimulus.

Taken together, evidence imply that people in general can correspond sound and tastes based on a match between musical and gustatory properties. Behind the complex combination of pitch, articulation, harmony and tonal patterns that make up a music, and behind the conglomeration of sugar, acids, fat, proteins and all stuff that compound food, the human brain has the ability of connecting the two modalities and extracting meaning. Although the consistency of crossmodal correspondences has been widely observed in the population, the explanations for these correspondences has yet to be determined (Guetta & Loui, 2017).

Sensory modalities can exert influence one another directly or indirectly. A direct influence occurs when the dynamics of one sensory modality entrains the dynamic of another, as might be observed with a mutual interaction between odour and taste where each one of them has been altered as a function of one another (Veldhuizen, Nachtigal, Teulings, Gitelman, & Small, 2010). However, for biological reasons, this specific kind of direct interaction can only happen for senses that use common brain structures, for instance, between the auditory, visual and tactile sensory modalities using the thalamus, or between taste and smell using the insula cortex (Kantono et al., 2016; Veldhuizen et al., 2010). Thus, regarding flavour-music interaction, more indirect mechanisms have been considered (Kantono et al., 2016).

The question of what mechanisms drives the capacity for these auditory and gustatory correspondences has not been empirically answered by researches. However, several hypotheses (although speculatives) and potential drives have been proposed (Knöferle & Spence, 2012; Spence, 2011). Some questions raised focus on whether these crossmodal associations are universal and innate or learned from social development, shaped by culture or region or even influenced by subjective preferences or pleasantness. (Kantono et al., 2016; Knoeferle et al., 2015).

2.2.2.3.1. Structure Matching

The first explanation regarding crossmodal correspondences can be addressed by the particularities of the neural systems used to code sensory information. Such as that based on Stevens's idea of intensity matching (Stevens, 1957) whereby an increase in stimuli intensity of one modality (regardless which one), can be mapped onto an increase in other property/dimension (Smith & Sera, 1992). Intensity matching explains the possibility of these crossmodal correspondences based on stimulus magnitude. Regarding auditory–gustatory correspondences, for instance, auditory loudness could be expect to map onto the intensity of a gustatory stimulus (Knöferle & Spence, 2012; Spence, 2011). These crossmodal associations could be thought as the result of the mechanisms underlying the cognitive system operation. Alternatively, two sensory modalities might be associated by being coded in nearby brain areas (Ramachandran & Hubbard, 2001), or even due to the principle of neural economy whereby the brain use similar mechanisms (regardless the distance in brain areas involved) to process information from different sensory dimensions that can happen to be associated as consequence (Spence, 2011).

2.2.2.3.2. Statistical co-occurrences

The second possible explanation for crossmodal correspondences can be addressed by an adaptive response internalized at some point by the brain to catch the statistical regularities of the environment and hence facilitate multisensory integration (or prediction) (Knöferle & Spence, 2012; Spence, 2011; Spence & Deroy, 2013b). Regarding crossmodal correspondences between colour and taste, they might appear to achieve an evolutionary purpose since for example red colour and sweet taste are both cues of ripeness and nutritional value in fruit (Spence et al., 2010). This association mechanism reached at some point benefited object recognition and therefore, increased the likely of individual survival. However, the adaptive reasons for the auditory-gustatory mappings are less clear (Knöferle & Spence, 2012). According to Spence (Spence, 2012b), the pitch-taste correspondence might have its origin in the innate orofacial gestures that many species make in response to gustatory stimuli featuring basic tastes at birth. Naturally, reactions to bitter tastes include protruding the tongue outwards and downwards, resulting in lower-pitched speech sounds when exhaling. This could be apparently an evolutionarily adaptive strategy since several bitter tasting foods being poisonous. By contrast, typical reactions to sweet tastes involve outwards and upwards tongue positions, which result in higher-frequency sounds (Knöferle & Spence, 2012; Spence, 2011, 2012b; Spence & Deroy, 2013b).

These crossmodal associations can be thought as a form of statistical co-occurrence experience of an individual generating specific auditory cues in response to specific gustatory input early in life.

It could be expectable that crossmodal correspondences based on these statistical regularities are more likely to be universal than those mediated by semantic for instance, given that the resonance properties of objects are determined by physic laws and not culture, and therefore shared by all individuals (Knöferle & Spence, 2012; Spence, 2011).

2.2.2.3.3. Hedonic matching

Another approach that could explain these auditory-gustatory correspondences is related with the idea that people match tastes that are perceived to be unpleasant (e.g bitter) with the sounds that are considered less pleasant (e.g trombone sounds) and more pleasant tastes (e.g sweet) with more pleasant sounds (e.g piano) (Crisinel & Spence, 2012; Crisinel & Spence, 2010). It might be considered that certain crossmodal correspondences may be mediated by the similar emotional valence of the stimuli of each modality (Knöferle & Spence, 2012).

The common emotional associations (such as pleasantness or arousal) shared by the different stimuli involved are not only related to the timbre of musical instrument but also to other musical patterns as the degree of dissonance. Thus, for instance, the association between consonant musical harmony and sweetness may be attributable to people finding both stimuli pleasant (Wang, Woods, & Spence, 2015). Such a hedonic matching account between seemingly unrelated stimuli presented in different sensory modalities emphasize the pleasantness as a reliable link between them (Guetta & Loui, 2017; Kantono et al., 2016; Wang et al., 2015). More pleasurable (positively-valenced) music and taste stimuli can provoke stronger crossmodal associations (Guetta & Loui, 2017).

In a research (Guetta & Loui, 2017) participants were asked to evaluated the pleasantness of different musical pieces composed on the basis of each one of the basic tastes. The results showed that participants reacted most pleasantly to the sweet musical pieces which were warmth, vibrato and legato and that were played with the least intensity in bow pressure, being acoustically associated with less loudness, less brightness and slower attack (Guetta & Loui, 2017). The bitter and sour musical pieces, on they turn, where played with more tension and roughness with quicker fluctuation in amplitude provoking a less pleasant reaction (Guetta & Loui, 2017). The sour musical pieces highlighted dissonant intervals and proximal frequency components, triggering an unpleasant response (Guetta & Loui, 2017). The salty musical pieces with staccato articulation and faster tempo were energetic and light, had quick attacks and releases of notes, and was considered relatively pleasant by participants (Guetta & Loui, 2017).

Although the growing body of researches regarding these correspondences, the evidence is still scarce. The results of Crisinel and Spence found that unpleasant tastants as very salty tastes did not, in every instance, result in a selection of unpleasant sounds (e.g trombone sound). In other study (Crisinel & Spence, 2012) showed that while instrument choice could be influenced by pleasantness rated of gustatory stimuli, the same did not happen with the pitch choice. These achievements highlight the possibility of another mechanisms involved and the importance of more researched regarding the nature of these matchings (Knöferle & Spence, 2012).

2.2.2.3.4. Semantic matching

According Knöferle and Spence "*semantically mediated correspondences may develop if the same terms or concepts are used to characterize sensations arriving from different sensory modalities"* (Knöferle & Spence, 2012) . One of the most cited examples of these shared linguistic labels would be the use of the expressions '*high*' and '*low'* to describe perceptual sensations of modalities as different as auditory pitch and spatial configuration. On this regard, researches have evidenced correspondences between high pitch and high spatial elevation, and low pitch with low spatial elevation (Melara & O'brien, 1987; Pratt, 1930; Rusconi, Kwan, Giordano, Umilta, & Butterworth, 2006).

The semantic coding hypothesis (Martino & Marks, 1999) can be one possible explanation for this capacity to map sensory cues regarding common semantic features. According to this hypothesis, these crossmodal interactions can occur almost exclusively on a later stage of the information processing (rather than on perception), after receiving the information from different senses this is coded into a common, abstract representation (probably semantic or verbal) (Knöferle & Spence, 2012; Martino & Marks, 1999; Spence, 2011).

As mention before, regarding crossmodal correspondences between gustatory and auditory modalities the metaphorical use of taste words to describe auditory stimulus (e.g '*sweet*' melody) can be encountered (Mesz et al., 2011). However, taking into account the causality effect, it is difficult to understand whether the consistent use of some terms across different sensory modalities would be the cause or the consequence of a crossmodal correspondence (Knöferle & Spence, 2012; Spence, 2011). It is not clear whether people map, for example, the sweet taste to what they perceived as sweet music as result of a coincidently terminology used to describe both modalities, or rather they use terminology as result of a non-semantic relation between the two sensory modalities. If the last approach is the correct, more research should be conducted to achieve a better understanding regarding the underlying mechanism that drive the usage of such terminology (Knöferle & Spence, 2012).

The previous explanations should not necessarily be assumed as mutually exclusive alternatives, but as possibilities complementing and supporting each other, both regarding specific and general crossmodal correspondences (Spence, 2011).

Other researches can also lead to a growing awareness regarding the culture's influence in crossmodal correspondences, highlighting the role of individual's musical socialization, the language and semantic issues and/or even the particularities of each cultural food habits (Knoeferle et al., 2015).

3. MATERIALS AND METHODS

3.1. Aims and Hypothesis

The subject of the present study is the crossmodal correspondences between auditory and gustatory properties being its main aims and hypothesis described below:

General:

To understand the influence of background music on the perception of taste.

Specific:

To evaluate the effect of musical congruency on food perception. Namely, whether music having different auditory properties (Music A (sweet music) - medium-high pitch, low dissonance, low speed, soft, low articulation (*legato*), low loudness and low psychoacoustic roughness; and Music B (sour music) - high-pitch, high speed, high articulation, high dissonance and high psychoacoustic roughness) influence the perceived intensity of the sweet and sour basic tastes and the creaminess in a dessert.

Hypothesis:

When the music is congruent with certain sensory attribute of the dessert, the perception of this attribute is intensified.

H1. The *sweet* music will enhance the perception of the sweet basic taste and of the creaminess intensity of the dessert

H2. The *sour* music will enhance the perception of the sour basic taste and of the roughness intensity of the dessert

H3. The overall experience will be considered more pleasant with *sweet* music than with *sour* music.

3.2. Food stimuli

In order to test the effect of the sound stimuli on the tasting experience, namely on the perceived intensity of taste and texture, a dessert composed of only one element with two different basic tastes, sweet and sour, was chosen as food stimulus for the study here described.

The musical types identified as congruent with the four basic tastes have different characteristics, and the choice of tastes to consider – the sweet and sour tastes – was based on the polarity of their association with music (slow *vs* fast, consonant *vs* dissonant).

Another criterion in the choice of the dessert was related with its texture that should not introduce any sound by itself, to avoid any interference with the auditory stimulus of the experiment.

The dessert selected was a passion fruit mousse (Annex A) in which the two basic tastes were clearly evident, without overlapping each other. These characteristics were quantified measuring the pH (using a pH meter Checker by Hanna®) and soluble solid contents (using a hand refractometer series 300 by Zuzi®). The pH was 5,2 and the total soluble solids content was above 30 Brix degree (the limit for the refractometer available).

After the preparation of one batch with the necessary amount of the dessert required for all tests, it was equally distributed into 180 portions, having about 20 g each. These were served in plastic containers labelled with a three-digit numbers randomized codes, corresponding to the sound stimulus used for its tasting test.

The amount in each sample was defined considering two main aspects: *i)* it should be enough to allow a good perception by the participants of the attributes being evaluated; *ii)* it should be small enough to prevent saturation and satiation throughout the tests, which involved the tasting of three samples.

It was a concern to guarantee an identical amount of dessert in each sample, and exactly the same visual appearance and flavour, to ensure that, as far as possible, any change in participant's responses could be attributed to the background sound used in each moment of the experiment, and not to any individual difference in the samples themselves.

Bearing in mind the influence of temperature in basic tastes perception, the planning of the tests was made in order to minimize, as much as possible, any variation. The samples were held in the refrigerator until just before being served and the temperatures were checked, with a thermometer, being for all test 8 ± 1 ºC.

Figure 3.1 Dessert samples

3.3. Auditory stimuli

3.3.1. Musical pieces' pre-selection

Previously to the final selection of the musical pieces to use for the sensory analysis tests, a pre-selection of two "*sweet*" musical pieces and two "*sour*" musical pieces was made, based on the existing knowledge about crossmodal correspondences between basic tastes and sonic elements (pitch, articulation, loudness, duration and harmonic dissonance) as proposed by Mesz *et al.* (2011). This pre-selection was conducted by a professional musician.

The "*sweet*" musical pieces selected were *Nocturne Op.9 No.2 in E flat major*, by *Fryderyk Chopin* played in piano and *Piano Concert No.21 Andante in C major*, by *Wolfgang Amadeus Mozart* played by orchestra and piano.

The "*sour*" musical pieces selected were *Capriccio No.24 in A minor,* by *Niccolò Paganini* played in violin and *The flight of the bumblebee*, by *Nikolai Rimsky-Korsakov* played by orchestra.

In order to identify which of these musical pieces presented a stronger congruence with sweet and sour tastes and, therefore, select those to be used later in the experimental procedure, a focus group whose participants were musicians was conducted.

3.3.2. Focus group

A focus group is a social research method, especially used for the analysis of subjective themes that raise divergent opinions, which involves the sharing, discussion and clarification of points of view and ideas (Hennink, 2013; Puchta & Potter, 2004).

The focus group for this study was composed by 5 females, aged between 20 and 54 years old. All participants had a solid musical experience background (playing instruments like piano, guitar, flute and violin) and knowledge about the several musical parameters to be evaluated.

A plan for the session was developed (Annex B) (Bader & Rossi, 1998; Krueger & Casey, 2002) and the session started with an overall introduction about the research aims. The participants were also enlightened about the importance of choosing and validating the most congruent musical pieces with the basic tastes of the dessert. Then, the participants introduced themselves to the group and a comfortable atmosphere was provided.

Free association exercises between the basic tastes and musical characteristics were made and, after that, a sensory test was performed with the dessert developed for research (passion fruit mousse), containing the two basic tastes (sweet and sour). Each participant was instructed to sequentially taste each given sample in silence and while listening to the four different musical pieces, and to mark, at any part of the line scales in the form provided, the intensity perceived for each one of the two tastes. Participants were aware that each dessert sample was exactly the same across the experiment and the only changeable element would be the sound of the musical pieces heard. However, they did not know which music would enhance the perception of one taste or the other one.

Additionally, the characteristics and use of the scale for evaluating the intensity of perceived tastes was briefly explained, in order to avoid misunderstandings and bias in answers. The scales for all the moments were on the same form and participants could visualized their previous answers (Annex C).

The sequence of the different moments was: silence; *Nocturne Op.9 No.2 in E flat major*, by *Fryderyk Chopin* (music 1); *Piano Concert No.21 Andante in C major*, by *Wolfgang Amadeus Mozart* (music 2); *Capriccio No.24 in A minor*, by *Niccolò Paganini* (music 3); and *The flight of the bumblebee*, by *Nikolai Rimsky-Korsakov* (music 4).

After the sensory tests, information about the conclusions of other research studies (Crisinel et al., 2012; Crisinel & Spence, 2009, 2010; Crisinel & Spence, 2010; Knoeferle et al., 2015; Kontukoski et al., 2015; Mesz et al., 2012, 2011; Wang et al., 2015) was presented to the participants, the relevant musical parameters introduced (pitch, articulation, loudness, duration and harmonic dissonance), with a small contextualization about each one of them. For a better understanding of these aspects, the graphics by Mesz *et al.* (2011) (Annex D) were also handed to participants, as well as the musical sheets for each piece (Annex E), in order to promote a more conscious discussion and a critical reflection considering the characteristics of the musical pieces being discussed, and the previous sensory tests results. Finally, the selection of the musical pieces to be used in the sensory tests was performed.

3.4. <u>Sensory Analysis</u>

3.4.1. Participants and Recruitment

The participants were recruited on FCT university campus through previous announcement and request for collaboration at the Chemistry Department.

Before taking part on this study, participants were informed that they would be tasting passion fruit mousses (they would have different experiences where free passion fruit mousses would be offered, in return for rating their sensorial attributes), but they were never informed about the purpose of the study, to avoid bias.

Voluntary participants registered themselves by sending an e-mail. There was no screening of the volunteers considering gender, age, ethnicity, musical training, or any other aspect.

After registration, they had the chance to choose the time slot from a set of different options. The participants were carefully allocated in groups, respecting their availability, but also assuring that there was a balanced number of participants in each session of the tests. The participants were also instructed to avoid smoking at least one hour before the tests, as well as drinking coffee or eating spicy foods two hours before, or using very strong perfumes during the tests.

In the beginning of the session, the participants filled their written informed consent (Annex F) and all of them reported not having a cold or other impairment on their senses of taste, smell or hearing at the time of the study, as well as any intolerance or allergy (Annex G). They were also aware that they could freely give up the participation at any stage of the study.

The 60 participants that enlisted themselves for this study and concluded the sensory tests had the gender and age profile shown in table 3.1.

Table 3.1 Gender and age profile for all participants that concluded sensory tests

Age (years)					Gender	
<25	**25-34**	**35-45**	**46-55**	**>55**	**Female**	**Male**
37%	22%	35%	13%	17%	63%	37%

Beside the availability to participate in the study and no previous knowledge of sensory impairments, the participants were tested on their ability to distinguish and recognize basic tastes. These pre-tests were made previously to the sensory tests, in order to understand if participants could recognize the basic tastes present in the dessert they would taste later (see 3.4.1.1.1.). A familiarization with the unstructured scale used to mark the perceived sweetness, sourness and creaminess was also made (see 3.4.1.1.2.).

3.4.1.1. Participants' screening

A participants' screening was performed using some pre-defined criteria, to avoid compromising the results accuracy. Three main points were considered as criteria for excluding participants from the study: *i)* The ability to recognize basic tastes. The pre-test was performed in order to understand whether participants would be able to recognize the basic tastes of the dessert tasted later. Initially, based on literature (Faria e Yotsuyanagi, 2018), it was thought to considered, the responses of participants who match 75% in the basic tastes distinction, regardless what basic taste they had failed. However, it was considered a more accurate option to excluded all participants that had failed in at least one of the basic tastes of dessert (sweet and sour), regardless whether it was their only error. *ii)* The ability to correctly perceive and mark on the unstructured line scale the different intensity degrees regarding sweet and sour taste. The participants who wrongly considered the most intense solution as less intense, or the opposite were excluded from the study. *iii)* The ability to recognize the intensity of the basic tastes in the dessert different from nothing sweet and/or sour. Since the dessert contained in itself components responsible to confer the sweet and sour basic tastes (as proved by physicochemical analysis) the participants who classified the intensity of at least one of them as not sweet and/or sour in the sensory analysis tests were excluded.

3.4.1.1.1. Recognition of basic tastes test

For it purpose, four basic taste solutions were prepared: sweet (sucrose 24g/L), salty (sodium chloride 4g /L), sour (citric acid 1g /L) and bitter (denatonium benzoate in concentration number 3 from *Coffee consulate*® brand). The umami basic taste was not considered since it is not familiar enough in Western population and languages (Hopia; Ihanus, 2014).

Samples were given to participants in six coded containers with the same appearance, placed in a random order, each one of them containing 30 ml of each of the four solution referred, pure water and a repetition of one of the basic tastes solution.

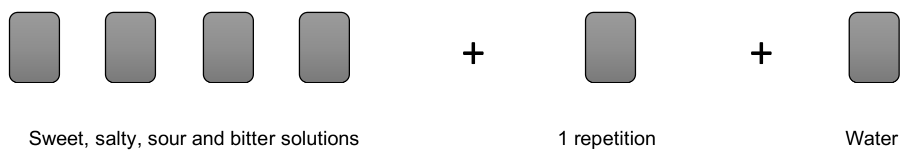

Figure 3.2 Scheme of samples for basic taste recognition test

For the evaluation of the basic taste solutions, the participants were instructed to taste each sample and swirling it a few seconds in the mouth until they could recognize the basic taste. After tasting each solution, participants were asked to fill out the form with the sample number and the basic taste perceived (Annex G). Taking into consideration the common misunderstandings between sour and bitter tastes (Wang et al., 2015), in order to avoid possible mistakes related with that, some elucidating examples were given associating bitter as the basic taste perceived when drinking coffee and sour as the basic taste perceived when eating lemon. The participants who did not want to swallow the samples had proper containers to discard them. Between each sample participants were instructed to drink water to wash their mouth.

3.4.1.1.2. Familiarization with scale

There was some uncertainty regarding the participants' ability to use an unstructured 9 cm scale. In order to overcome that and make easier and more accurate the filling of the sensory forms, a training with these scales was performed, immediately before starting the sensory tests.

30 ml of two solutions for each basic taste (sweet and sour) were given to participants, in three-digit coded containers with the same appearance. The two sweet solutions were initially tasted and subsequently the two sour solutions were tasted. For each group solutions were tasted in an increasing intensity order (from less to more intense solution). Solution had different degrees of intensity. For the sweet taste, a low sweet solution (14 g sucrose/L) and a considerably sweeter solution (51 g sucrose/L) were used. Regarding the sour taste, a low sour solution (0,5 g citric acid/L) was given as well as a considerably sourer solution (1,5 g citric acid/L). Participants were asked to taste each sample and to mark on the correspondent line scale the perceived intensity (Annex H). Previously to the tasting, participants were instructed about how to use the scale.

Figure 3.3 Scheme of samples for scale's familiarization

3.4.2. Instruments

A sensory analysis form to be filled by the participants during the tests was developed. (Annex I).

The aim of this tool was to gather quantitative information about participants' perception of relevant sensory attributes previously identified. It was decided to ask participants to perform a hedonic analysis, for which the target attributes considered were appearance, colour, aroma, texture, flavor, and overall experience. Also, and more important, to the aims of the study, a quantification of the perceived intensity of the sweet and sour tastes, and also of the creaminess of the dessert was performed.

Two types of scales were used according to the nature of the attributes to be evaluated.

9 points Likert scale

Participants were asked to rate in a 9 points Likert scale (Lim, 2011) how pleasant or unpleasant they considered the attributes appearance, colour, aroma, texture and flavor, corresponding 1 to extremely unpleasant and 9 to extremely pleasant.

The general perception was also measured through a 9 points Likert scale, but instead of asking about the pleasantness of the attributes, participants had to rate how they liked or disliked the overall experience, where 1 corresponded to extremely disliked and 9 to extremely liked.

A 9 points Likert scale was chosen, instead a 5 or a 7 points one, in order to increase the sensitivity of the measurements (Pearse, 2011).

It was expectable that participants were already familiarized with Likert scales, it was also considered that their use for rating was intuitive, thus no familiarization with this scale was performed.

Unstructured 9 cm scale

The evaluation of perceived intensity of particular sensory attributes of taste (sweetness and sourness) and texture (creaminess) were the main focus on this study. For that purpose, an unstructured 9 cm scale was used, where the intensity of the basic tastes (sweet and sour) and creaminess increased from the left to the right. There were numbers on the line as reference (where 1 was not sweet/sour/creamy and 5 was very sweet/sour/creamy) but participants were informed that they could mark, with a vertical line, any part of the line scale regardless being over a number or between them. It was chosen to use this scale instead of a Likert scale, since it allowed to detect with more accuracy small differences in the perception of intensity as participants could freely mark the intensity at any part of the line (Greene, Bratka, Drake, & Sanders, 2006).

3.4.2.1. Instruments testing and enhancement

To evaluate if the procedures and the instruments were suitable and feasible, a simulation session was performed with 9 participants, 67 % females and 33 % males of which 22 % were aged under 25 years old, 56 % between 25 and 34 years old, 11 % between 46 and 55 and 11 % above 55 years old.

Participants went through all experimental procedures, including the pre-tests and the sensory tests. From this session it was possible to understand less clear aspects of the forms and enhance them, in order to achieve a more suitable version for the sensory tests. Besides the form adjustment, this session was crucial to improve the communication and necessary explanations relevant for each step of the experiment.

3.4.3. Sensory Tests

The sensory tests took place at room 218 of the Chemistry Department at FCT-UNL. This room was strategically chosen due the proximity with the gastronomy lab, where the samples were prepared and stored. However, participants entered and exited the facility without passing through the gastronomy lab, what prevented them from having physical or visual access to information that could, in any way, bias their responses.

As the room did not have booths available for these tests, participants were seated in the original classroom layout, with only one participant in each table, preventing them to face each other.

A comfortable environment regarding the temperature, humidity, ventilation and illumination was guaranteed to avoid distraction. It was also a concern to maintain the area as noise free as possible, to avoid interference with the different musical pieces and the silence required for the study.

Figure 3.4 Sensory tests room

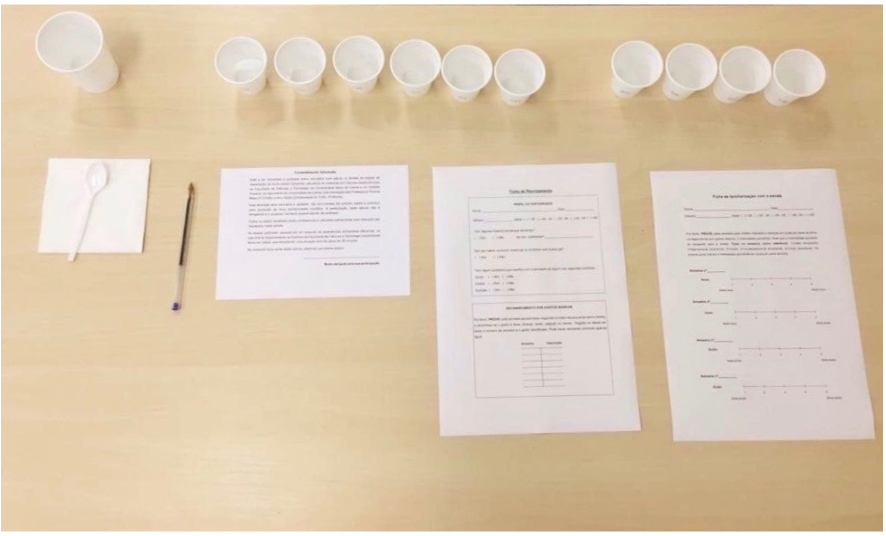

Figure 3.5 Pre-tests materials

The sensory tests, were performed immediately after the basic tastes recognition tests and the familiarization with the scale. In this stage, each participant experienced three different moments, in different orders:

- Control – the participants tasted the dessert in silence, with as little outside influence as possible.
- Experience A – the participants tasted the same dessert while listening a musical piece that expectably would enhance sweet taste of it - *Nocturne Op.9 No.2 in E flat major*, by *Fryderyk Chopin*.
- Experience B – the participants tasted the same dessert while listening a musical piece that expectably would enhance the sour taste of it – *Capriccio No.24 in A minor*, by *Niccolò Paganini*.

The musical pieces for the experiences A and B were listened as background music (no headphones involved) in the sensory tests room. The sound source was a laptop and the sounds' volume was measured with the app *"Decibel X"* and it was kept constant across the sessions. 71dB was registered for *Nocturne Op.9 No.2 in E flat major*, by *Fryderyk Chopin* and 76dB for *Capriccio No.24 in A minor*, by *Niccolò Paganini*.

Randomizing the order of the three experiences was an important issue. Hence, participants experienced the three tests in different orders. The number of participants experiencing each of the possible combinations was balanced to avoid bias due to the sequence of tests. There were 6 possible ordered combinations for the three tests:

Control – Experience A – Experience B	Control – Experience B – Experience A
Experience A – Control – Experience B	Experience A – Experience B – Control
Experience B – Control – Experience A	Experience B – Experience A – Control

To achieve randomization, 6 sessions, in which the three experiments occurred sequentially, were organized in different slots along the same day, and in each one of the sessions the sequence was different (each one of the above). The participants were divided into 6 groups having each approximately 10 tasters each. All tests occurred under exactly the same conditions.

The samples were given to the participants in containers coded with a three-digit number, where each number corresponded to each different moment test (control, experience A and experience B). Although the participants were tasting exactly the same dessert throughout the experiment, they were not aware of that.

At the beginning of each test, each participant received a dessert sample and the sensory form for filling. At each new test, they received a new dessert sample and a new sensory form and the previous one was removed. Tap water to neutralize the taste of the preceding dessert was available during the whole experimental procedure and participants were encouraged to drink it.

At the end of the experiment, that lasted for approximately 30 min for each group, the participants were instructed to leave the room without discussing any details with the next group of participants.

3.4.4. Statistical Analysis

The sensory analysis data, regarding appearance, colour, aroma, sweetness, sourness, creaminess, texture, flavour and overall experience, were submitted to analysis of variance (ANOVA), at 5% probability by the Ducan's Multiple Range Test and Tukey's multiple comparison tests ($p \leq 0.05$)

All the statistical analyses were performed by the XLSTAT 2017.6.48089 software version 0.7 for Windows (Adinsoft, Paris, France).

4. RESULTS AND DISCUSSION

4.1. Focus Group

Despite a previous general unawareness about any kind of relationship between music and taste perception, most participants admitted they had already described a music using taste words in an unconscious way. They reported the word "sweet" as the most used to describe slow, soft and pleasant musical pieces. Although less usually, some of them had already used the *bitter* and *sour* words to describe aggressive musical pieces.

The results are presented in table no.4.1. To further details see Annex J.

Table 4.1 Average values of sensory evaluation results regarding sweetness and sourness for tests with different auditory stimuli. The values are presented in centimetres (cm).

	Music 1	Music 2	Music 3	Music 4	Silence
Sweetness	7,340 A	5,880 AB	5,020 B	4,500 B	5,260 B
Sourness	3,500 C	4,180 BC	5,920 AB	6,320 A	4,920 ABC

Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

The results show that in silence 60 percent of participants considered the dessert sweeter (5,260 ± 0,636) than sour, whereas 40 percent considered the opposite (4,920 ± 0,586). However, it was consensual among participants that the two tastes were well balanced.

All participants felt a great difference in taste perception between the tasting in silence and those with the musical pieces, suggesting that music had a substantial influence in taste perception. It was mentioned by participants that it didn't seem they were eating the same dessert throughout the different moments. This difference perceived was congruent with the crossmodal correspondence between music and taste (Crisinel et al., 2012; Crisinel & Spence, 2009, 2010; Kontukoski et al., 2015; Mesz et al., 2012, 2011; Wang et al., 2015), since the sweetness perception of the dessert was enhanced while they were listening musical pieces 1 and 2 and the sourness perception was enhanced while they are listening the musical pieces 3 and 4.

For the two "sweet" musical pieces, the sweet intensity perceived was stronger when listening to music 1 (7,340 ± 0,636) than when listening to music 2 (5,880 ± 0,636), for all participants, having this difference statistical significance. However, the two "sour" musical pieces raised divergent intensity perceptions. 60 percent of participants considered that music 3 increased strongly the sour taste, whereas 40 percent considered this for the music 4. Although the average of intensity of sourness perception was bigger when participants were listening the music 4 (6,320 ± 0,586) than when they were listening the music 3 (5,920 ± 0,586), this difference did not have statistical significance.

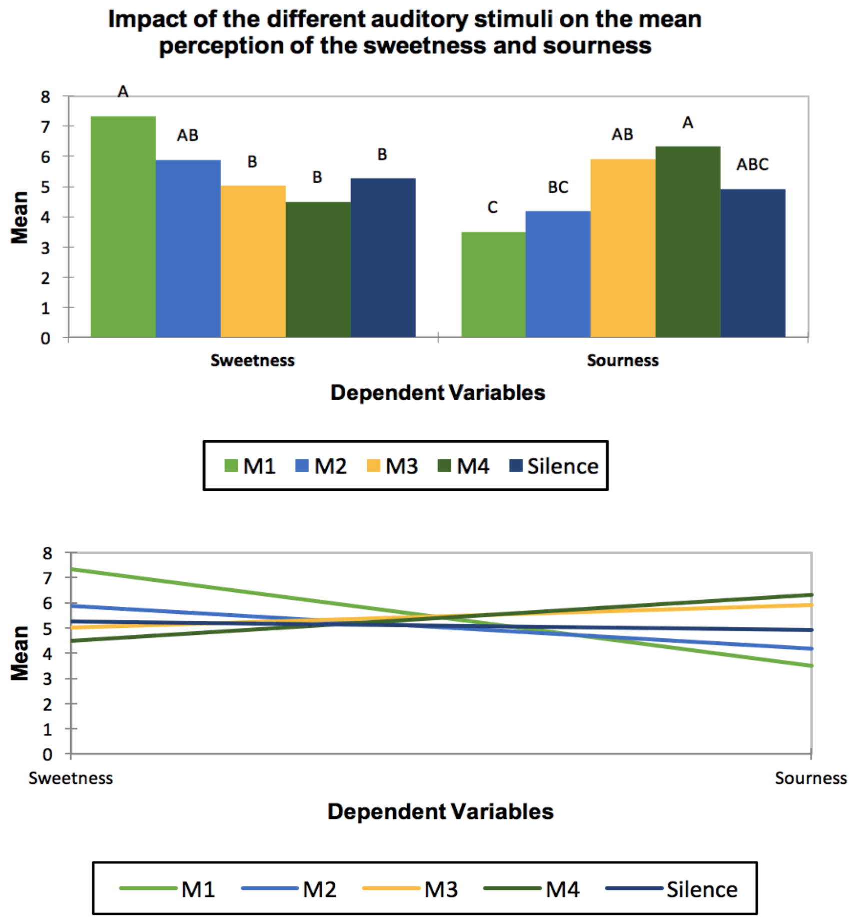

Figure 4.1 Graphic of the impact of different musical pieces on sweetness and sourness perception. Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

After making participants aware of the specific crossmodal correspondence between music and basic taste, it was possible to reliably confirm music 1 as the best choice for sweet taste. The sour musical pieces were the subject for further discussion. The musical parameters of each music were carefully analysed while participants heard the musical pieces 3 and 4 again. With that information in mind, all participants agreed that the music 3 was the best option for sour taste, even those who had felt a sourer intensity perception with music 4. Besides, an uncomfortable and intriguing sensation regarding the music 4 was mentioned, which could create an unpleasant experience.

With a consensual opinion among participants, the musical pieces selected were:

- *Nocturne Op.9 No.2 in E flat major, by Fryderyk Chopin* played in piano for sweet taste;
- *Capriccio No.24 in A minor – Niccolò Paganini* played in violin for sour taste.

This focus group was extremely useful for the musical choice and validation.

On the one hand, the sensory experience allowed to conclude that, even without any knowledge about correspondences between basic tastes and music, the participants' taste perception changed according to the music they were listening while eating the dessert and these differences were congruent with those reported in the literature. It was interesting to observe that despite the consistency in results, no participant had exactly the same perception, emphasizing personal subjectivity in perception.

On the other hand, the discussion and sharing of opinions, based in the sensory test done and in the musical background of each participant, was very rich and promoted a deep analysis of the musical pieces and, thus, a more congruent decision for the experiment.

4.2. Sensory tests

4.2.1. Participants Description

From all participants that took part in sensory tests, 11 participants (18 percent) were excluded from this study. From these, 4 participants were excluded because they were not able to recognize the sweet or sour basic tastes, 3 participants were excluded because they were not able to correctly perceive and mark on the scale the intensity of the sour basic taste and 5 participants were excluded because they rated as not sweet or sour the perceived intensity of basic tastes of the dessert during the sensory analysis. One of these participant failed in more than one of these criteria (recognition of basic tastes and zero rating of the perceived intensity of basic tastes).

Thus, for this study 49 participants were considered. The gender and age profile are shown in table 4.2.

Table 4.2 Gender and age profile for participants considered for the study

Age (years)					**Gender**	
<25	**25-34**	**35-45**	**46-55**	**>55**	**Female**	**Male**
10%	23%	35%	14%	18%	65%	35%

4.2.2. Results

The evaluation of intensity perception of the particular sensory attributes of taste (sweetness and sourness) and texture (creaminess) while different auditory stimuli were presented were the main focus on this study. However, other sensory attributes were evaluated in order to reach an overview about how pleasant or unpleasant participants perceived them and, at the same time, decentralize the attention of the participants from the main focus of the study.

The results are presented in table 4.3. To further details see Annex K.

Table 4.3 Average values of sensory evaluation results for tests with different auditory stimuli

	Appearance	Colour	Aroma	Sweetness*	Sourness*	Creaminess*	Texture	Flavour	Overall Experience
Sour Music	7,061 A	7,143 A	6,959 A	49,612 A	45,000 A	62,918 A	7,959 A	7,612 A	7,592 A
Silence	7,020 A	7,041 A	7,082 A	49,755 A	41,612 AB	63,612 A	7,939 A	7,653 A	7,633 A
Sweet Music	7,163 A	7,082 A	6,755 A	48,878 A	36,163 B	61,735 A	7,755 A	7,755 A	7,735 A

*The values are presented in millimetre (mm)

Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

Considering all results, it is possible to find some small modulating effect on sensory attributes perception, although this did not reach statistical significance according to the Tukey's test. Only sourness intensity values for the tests listening to the sweet and sour musical pieces presented significant differences for Duncan's range test.

Although for most of the attributes the differences are very small and without statistical significance an analysis of the results is presented below.

4.2.2.1. Hedonic rating – appearance, colour, aroma, texture and flavour

Appearance and colour were the sensory attributes for which the auditory stimuli, had higher impact on the pleasantness rating, when compared with silence (reference condition), regardless of listening to the sweet or sour music. However, regarding the appearance, participants considered the dessert slightly more pleasant when listening to the sweet music (7,163 ± 0,155) than to the sour music (7,061 ± 0,155) whereas participants rated the dessert colour slightly more pleasant when listening to the sour music (7,143 ± 0,155) than to sweet music (7,082 ± 0,155).

By contrast, the aroma was the sensory attribute where the auditory stimuli had lower impact on pleasantness rating since it was on the silence condition that it was rating as slightly more pleasant (7,082 ± 0,178) than when sour (6,959 ± 0,178) or sweet (6,755 ± 0,178) music was playing on background.

Regarding texture, it was the sour music that had the highest impact on pleasantness rating, since participants considered this attribute slightly more pleasant while they were listening to the sour music (7,959 ± 0,115), followed by the silence condition (7,939 ± 0,115) and sweet music (7,755 ± 0,115).

Concerning flavour attribute, unlike texture, it was the sweet music that reported the highest impact on pleasantness rating, since it was considered as slightly more pleasant by participants while they were listening the sweet music (7,755 ± 0,109) compared with silence condition (7,653 ± 0,109) or sour music (7,612 ± 0,109).

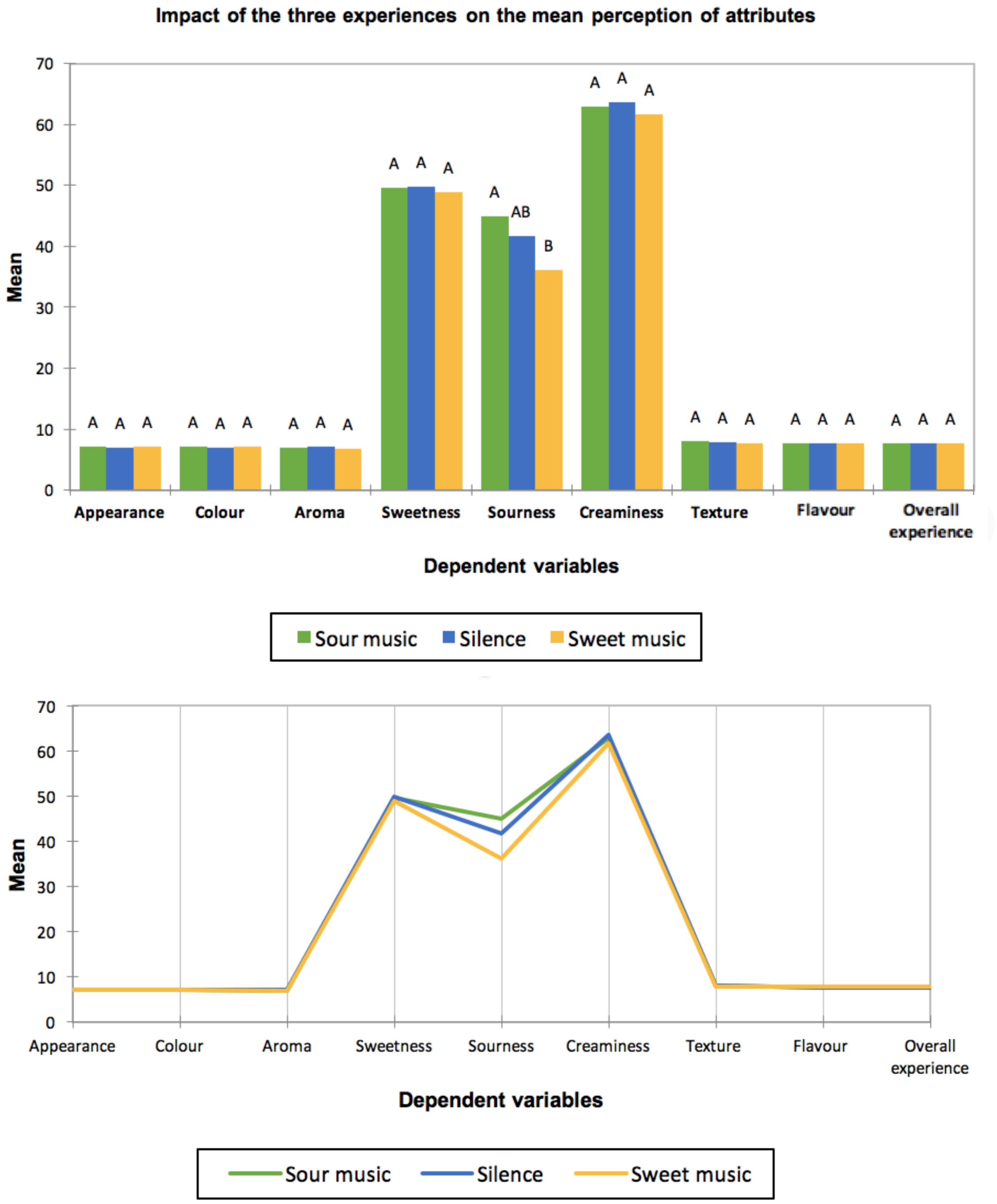

Figure 4.2 Graphic of the impact of the tests with different auditory stimuli on the average perception of all attributes. Values for each attribute with at least one equal letter, do not differ at the 5% level of significance

4.2.2.2. Liking rating – Overall experience

Regarding overall experience, results showed the same pattern observed for flavour, where sweet music had the highest impact on the liking rating, since participants like more the experience when they were tasting while listening the sweet music (7,735 ± 0,111) than with the silence condition (7,633 ± 0,111) or sour music (7,592 ± 0,111).

4.2.2.3. Perceived intensity rating – sweetness, sourness and creaminess

Overall, the sweetness and creaminess were the sensory attribute where the auditory stimuli had lower impact on the intensity perceived. Regarding sourness, it was the sour music that had the highest influence on sour intensity perception, since participants considered the dessert sourer while they were listening to the sour music.

4.2.2.3.1. Basic tastes

The results showed that in silence (reference condition) participants considered the dessert sweeter (49,755 ± 2,380) than sour (41,612 ± 2,814). This pattern did not change with the different auditory stimuli, since with sweet and sour background music the sweet perception intensity remains higher (48,878 ± 2,380 and 49,612 ± 2,380, respectively) than sour perception (36,163 ± 2,814 and 45,000 ± 2,814, respectively).

As mention before, participants considered the dessert sourer when they were tasting it while listening to the sour music (45,000 ± 2,814) when compared with when listening to the sweet music (36,163 ± 2,814), being this difference statistical significant. However, regarding sweetness, participants considered the dessert sweeter in silence (49,775 ± 2,380) than with sour music (49,612 ± 2,380) or even the sweet one (48,878 ± 2,380). Although the sweet music had not increased the sweet perception of dessert, the results showed that it had effect on decrease of sour perception of dessert (36,163 ± 2,814) when compared with sour music (45,000 ± 2,814) or silence (41,612 ± 2,814).

4.2.2.3.2. Creaminess

Creaminess was the attribute with the highest values for perceived intensity rating. On silence condition participants considered the dessert creamier (63, 612 ± 2,510) than with sour (62,918 ± 2,510) or sweet (61,375 ± 2,510) music, although the difference between this values is not statistical significant.

Table 4.4 Correlation Matrix

	Appearance	Colour	Aroma	Sweetness	Sourness	Creaminess	Texture	Flavour	Overall Experience
Appearance	**1**	**0,774**	0,217	-0,037	-0,106	0,270	0,372	0,216	0,190
Colour	**0,774**	**1**	0,315	0,030	0,032	0,207	0,390	0,269	0,259
Aroma	0,217	0,315	**1**	-0,028	0,128	0,155	0,230	0,403	0,465
Sweetness	-0,037	0,030	-0,028	**1**	0,051	0,113	0,108	-0,009	-0,062
Sourness	-0,106	0,032	0,128	0,051	**1**	0,094	0,115	0,027	-0,002
Creaminess	0,270	0,207	0,155	0,113	0,094	**1**	**0,498**	0,271	0,211
Texture	0,372	0,390	0,230	0,108	0,115	**0,498**	**1**	0,329	0,396
Flavour	0,216	0,269	0,403	-0,009	0,027	0,271	0,329	**1**	**0,808**
Overall Experience	0,190	0,259	0,465	-0,062	-0,002	0,211	0,396	**0,808**	**1**

The relevant values of correlation appear in bold.

The correlation matrix showed that there is a positive and strong correlation (R=0,808) between flavour and overall experience meaning that those who considered flavour more pleasurable also liked more the overall experience. Although not so strong as previous one, a positive and strong correlation (R= 0,774) between appearance and colour can also be observed thus, those who considered the appearance more pleasurable also considered the colour more pleasurable. Despite weaker than previous correlations, a positive and moderate correlation also occurs between texture and creaminess (R=0,498) evidencing that participants who considered the creaminess more intense also considered the texture more pleasant.

4.2.2.4. Results organized by groups regarding intensity of perception for each basic taste

Additionally, in order to understand whether the results would follow the same patterns with a more specific filter, they were divided in three different groups regarding the intensity of perception (high, medium and low) rated by participants for each basic taste. It was considered low sourness / sweetness when participants rated the taste between 0 and 3 cm ([0-3[), medium sourness/sweetness when they rated them between 3 and 6 cm ([3-6[), and high sourness/ sweetness when they rated them between 6 and 9 cm ([6-9]).

Regardless of the basic taste, the majority of the participants rated them on a medium level.

Table 4.5 Number of participants in each group regarding the intensity of perception of sourness and sweetness rated with the different auditory stimuli

	Sweet music	Sour music	Silence		Sweet music	Sour music	Silence
High sourness	8	16	11	**High sweetness**	20	17	14
Medium sourness	20	21	24	**Medium sweetness**	24	26	31
Low sourness	21	13	14	**Low sweetness**	6	6	4

It can be seen that the number of participants in each group of sourness levels varied considerably with the different auditory stimuli. With sour music playing on background, 16 participants considered the dessert as highly sour, whereas only 8 participants considered it when sweet music was playing instead. In the silence condition 11 participants rated the dessert's sourness as high. The number of participants that rated the dessert with a medium level of sourness did not show a great difference between each auditory condition. However, the same was not verified regarding the low sourness perception group, where the number of participants that considered the dessert as lowly sour is higher when the sweet music was being listening (21 participants), decreasing to only 13 participants with sour music and 14 participants in silence condition.

Regarding each group of sweetness levels, the number of participants did not vary much with the different auditory stimuli. However, it can be highlighted a slightly decrease in the number of participants that considered the dessert highly sweet with sweet music (20 participants) to 17 participants with the sour music.

The results of sweetness and sourness attributes with the different auditory stimuli organized by groups regarding intensity of perception of these basic tastes are presented in tables (4.6 and 4.7) and figures (4.3 and 4.4) bellow. To further details regarding other attributes see Annex L.

4.2.2.4.1. Sourness

Table 4.6 Average values of sweetness and sourness with different auditory stimuli divided for groups of sourness intensity perception. The values are presented in centimetres (cm).

	High Sourness		Medium Sourness		Low Sourness	
	Sweetness	**Sourness**	**Sweetness**	**Sourness**	**Sweetness**	**Sourness**
Sour music	5,888 A	6,706 A	4,138 B	4,519 A	4,938 A	1,577 A
Silence	4,891 A	6,609 A	4,950 AB	4,454 A	5,086 A	1,736 A
Sweet music	4,413 A	6,638 A	5,245 A	4,360 A	4,729 A	1,757 A

Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

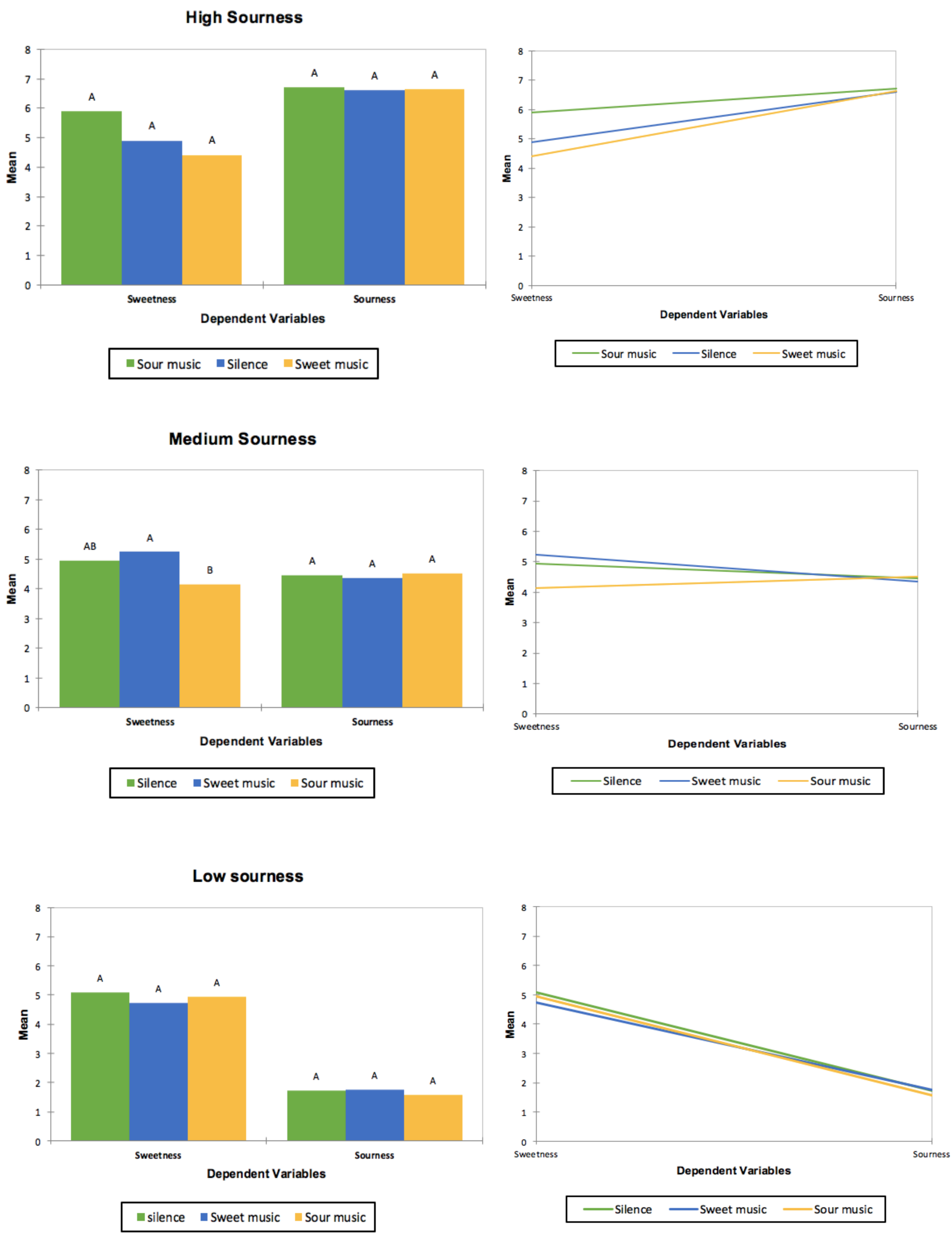

Figure 4.3 Graphics of the impact of the different musical stimuli on sweetness and sourness, divided by sourness intensity perception. Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

When the results were analysed based on the sourness intensity perception some small differences on sweet and sour perception with the different auditory stimuli were presented although they did not reach statistical significance. However, it is important to refer that regarding medium sourness intensity perception group, the sour music decreased significantly the sweet perception of the dessert when compared with the sweet music effect on the same group. It is possible to verify that participants considered the dessert significantly sweeter (5,245±0,370) when the sweet music was playing on background in opposite at when sour music was playing on background (4,138±0,361).

4.2.2.4.2. Sweetness

Table 4.7 Average values of sweetness and sourness with different auditory stimuli divided for groups of sweetness intensity perception. The values are presented in centimetres (cm).

	High Sweetness		Medium Sweetness		Low Sweetness	
	Sweetness	**Sourness**	**Sweetness**	**Sourness**	**Sweetness**	**Sourness**
Sour music	7,029 A	5,671 A	4,246 AB	3,777 A	2,200 A	4,317 A
Silence	6,686 A	4,264 B	4,561 A	3,990 A	2,200 A	5,125 A
Sweet music	6,705 A	3,740 B	4,129 B	3,813 A	2,133 A	3,250 A

Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

Regarding the different groups of sweetness intensity perception, once again, the results showed some small differences on sweet and sour perception of dessert but they did not reach statistical significance. However, it is worth to mention that for participants that considered the dessert highly sweet, the sour music had an increasing effect on sour perception of dessert (5,671±0,466) when compared with sweet music (3,740±0,430), being this difference statistical significant. For those who considered low sweetness, it is possible to note a great difference on sourness perception of dessert with sour music playing on background (4,317±0,699) or sweet music playing instead (3,250±0,699), however, this difference does not have statistical significance.

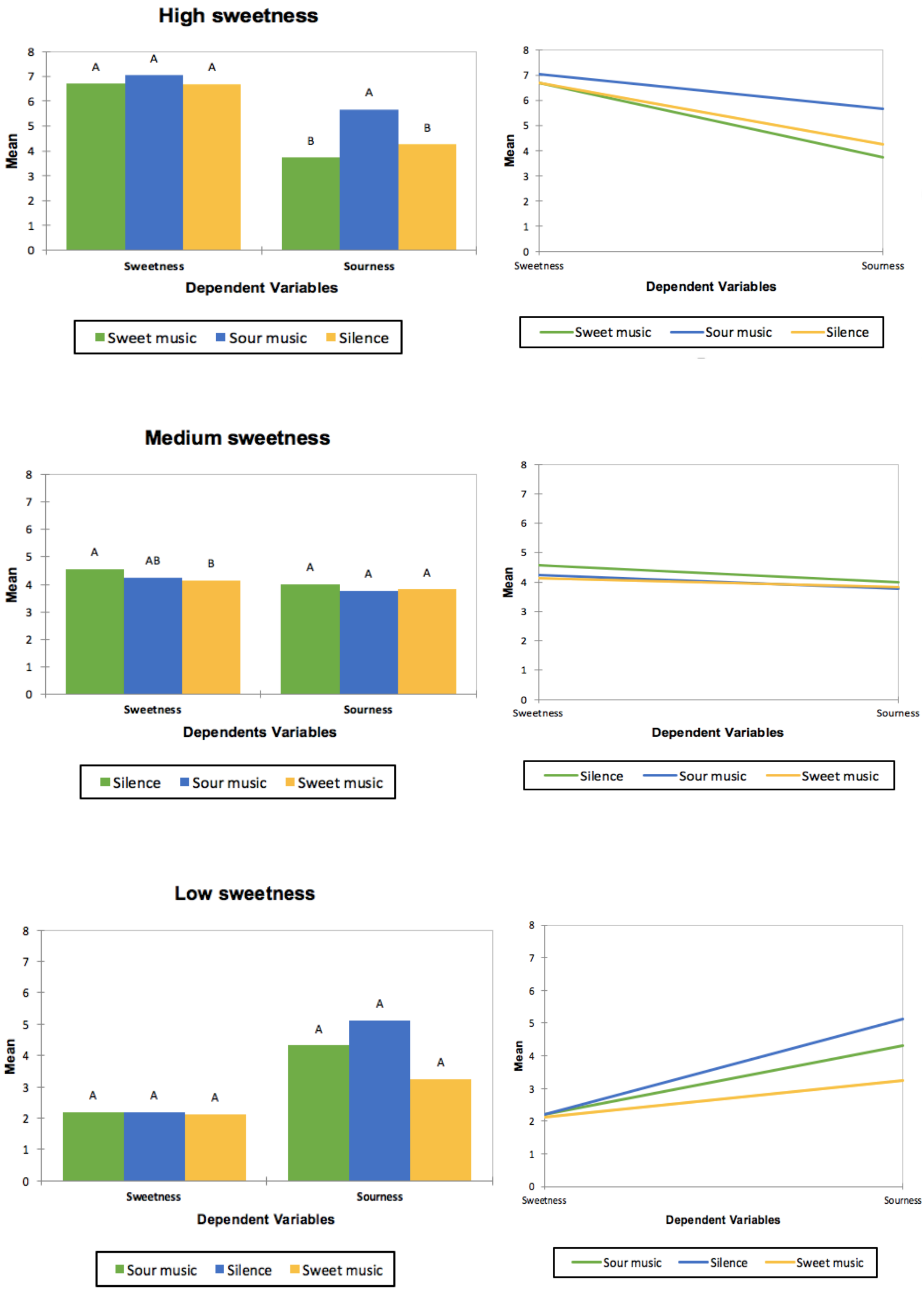

Figure 4.4. Graphics of the impact of the different musical stimuli on sweetness and sourness, divided by sweetness intensity perception. Values for each attribute with at least one equal letter, do not differ at the 5% level of significance.

4.3.3. Discussion

Although without significant difference, participants considered the flavour of the dessert more pleasant while they were listening to the sweet music, followed by the silence and the sour music conditions, which is in accordance with literature (Carvalho, Velasco, Van Ee, Leboeuf, & Spence, 2016; Guetta & Loui, 2017; Kantono et al., 2016; Knöferle & Spence, 2012). In the same way participants liked more the experience (overall experience) when they were listening to the sweet music, followed by the silence and sour music conditions. As already referred there is a positive and strong correlation between the flavour and the overall experience, whereby the more pleasant participants found the flavour of the dessert, the more they liked the experience. Results showed that in both cases sweet music was the auditory stimuli most associated with higher pleasantness and liking, whereas sour music was the one associated with less pleasantness and liking.

The positive or negative mood induced by background music can influence people's perception and evaluation of the food they are eating and could even be associated with changes in taste and smell sensitivity (Kantono et al., 2016; Spence, 2017; Spence & Piqueras-Fiszman, 2014). Thus, the hedonic valence of the music could influence the overall hedonic judgment of the food stimuli, being the pleasantness the connection between the sensory modalities (Carvalho et al., 2016; Guetta & Loui, 2017; Knöferle & Spence, 2012).

Sweet music is related to high levels of psychoacoustical pleasantness, which correspond to soft sound intensity and low roughness, that in turn, is related to consonance (Bronner et al., 2012). The sweet music in this experiment was played by piano, that has been described on literature as the most pleasant instrument sound at all pitches. This match between the timbre and the taste can largely be attributed to a matching of the pleasantness values of the two stimuli (Crisinel & Spence, 2010; Guetta & Loui, 2017; Knöferle & Spence, 2012).

Sour music, on the other hand, is related with high-pitched, loud and dissonant sounds, which correspond to high sensory sharpness, a psychoacoustical degree that is inversely linked to pleasantness (Bronner et al., 2012; Knöferle & Spence, 2012; Mesz et al., 2011). The higher dissonance levels of sour music can reflect the lesser sensorial pleasantness of this taste and has been related with painful and negative emotions (Mesz et al., 2011). Unpleasant sounds are associated with higher levels of psychological arousal than neutral or pleasant sounds, and as consequence an increase of anxiety and blood pressure. Thus, the unpleasant sensation could affect the overall pleasure of the food stimuli (Kantono et al., 2016).

It is important to highlight that although the sour music is unavoidably more unpleasant than the sweet music due to its specific musical pattern, it was a concern in the musical pre-selection and focus group selection to avoid unpleasant sounds that could be unbearable for participants, to make them focus on the sensory attributes of the dessert (Kantono et al., 2016; Kontukoski et al., 2015).

According literature, the congruency between music and food would lead to an increase in food pleasantness ratings, and for the same reason the tasting experience with an incongruent music would reduce pleasantness ratings (Wang (Janice) & Spence, 2015). In this case concretely, pleasantness and overall experience liking are probably more related with the pleasantness of music than congruency, since as the dessert had itself the two basic tastes present in auditory stimuli of the experiment, no one of the two music could be considered incongruent after all.

4.3.3.1. Basic tastes: sweet vs sour

As it was expected based on literature (Bronner et al., 2012; Crisinel et al., 2012; Crisinel & Spence, 2009, 2010; Crisinel & Spence, 2010; Knöferle & Spence, 2012; Kontukoski et al., 2015; Mesz et al., 2012, 2011; Wang et al., 2015), participants considered the dessert sourer when they were tasting it while listening to the sour music, when compared to the rating while listening to the sweet music, being this difference statistical significant. This result suggests that music congruency had a significant influence in sour taste perception.

The specific mechanisms behind these associations between music and taste are yet unclear (Guetta & Loui, 2017; Knöferle & Spence, 2012; Mesz et al., 2011; Spence & Deroy, 2013b). However, some possible causes could be suggested.

One attempt to explain this is the fact that music may activate superordinate knowledge structures that then prime a characteristic that is being perceived at the same time. Hence, it can be considered that the "sour" symbolic connotation of *Paganini*'s music prime a mental content linked with the sourness. This activation triggers an increase on perception of corresponding taste of the food stimuli (Kontukoski et al., 2015; Spence & Deroy, 2013a).

Another idea that could be put forward here is the use of the emotional valence of sound and taste stimuli as a mediating factor between the two sensory modalities (Guetta & Loui, 2017). The valence-matching hypothesis suggest that people match the sounds they perceived to be unpleasant with tastes that are similarly unpleasant (Guetta & Loui, 2017). Hence, as people in general consider the sour music and sour taste as more unpleasant, it can make sense to consider a transference effect, whereby the unpleasant sensation triggered by sour music reinforce and intensify a perception of similarly unpleasant taste on dessert (Carvalho et al., 2017; Guetta & Loui, 2017; Kontukoski et al., 2015).

A relevant issue that might be considered to understand the significant effect of sour music in sour taste perception is the colour of dessert. Colour can modulate people's perception of a certain taste presented on some food stimuli (Spence, 2017; Spence et al., 2010). In fact, there is a relation between the colours and the basic tastes where the green and yellow colours are associated with sour taste (Spence, 2017; Spence et al., 2010; Spence & Piqueras-Fiszman, 2014). In the test conditions, when a yellow dessert was offered with a sour music, the senses could have been combined in a multisensory congruent manner. Therefore, it was possible to observe a “superadditive” effect, whereby the different environment cues were combined to provide a multisensory effect that was bigger than the sum of its parts (Spence, 2017). The yellow colour of dessert enhanced more the sour sonic seasoning effect increasing the sour perception of the dessert. Reinforcing this congruency, it might be worth to highlight that participants considered the dessert colour more pleasant when the sour music was playing in background.

In opposite to what was verified regarding sourness and what was actually expected, the sweetness perception of the dessert was not enhanced while participants were listening sweet musical piece. In fact, participants considered the dessert sweeter in silence than with sour or sweet music. Actually, the dessert sweetness intensity perceived showed the lowest rating values when it was tasted while participants were listening to sweet music. These results, although not having statistical significance, were incongruent with crossmodal correspondence findings between music and taste presented on literature (Bronner et al., 2012; Crisinel et al., 2012; Crisinel & Spence, 2009, 2010; Crisinel & Spence, 2010; Knöferle & Spence, 2012; Kontukoski et al., 2015; Mesz et al., 2012, 2011; Wang et al., 2015).

Despite these results do not show that the sweet musical piece increased the perception of the sweet taste of the dessert as expectable, it can be observed that the sweet music decreases the sour perception, suggesting that a different approach can be considered when evaluating the music influence on intensity of basic tastes perception. The same pattern was also found when separating the results for group intensity of basic tastes. These findings could be the ground for an extended approach to these crossmoldal studies, whereby not only the influence of a congruent variable on taste is considered, but the impact of the incongruent stimuli on other tastes is also considered. In this study there is a sort of polarity between sweet and sour basic tastes and musical patterns associated, thus the condition can be ideal to identify the effect referred. An impact of the sweet music in the taste perception of the opposite taste (sour) can be assumed. Thus, although the participants did not perceive the dessert as sweeter, they found it less sour than in the others auditory stimuli conditions. Hence, based on the decreasing on the sour perception it can be possible to suggest that, even with no increase on sweet taste perception, the sweet music stimuli exerted an influence on overall sweetness perception through the balance of the sourness perception.

In fact, the acidity is a parameter only related with the acid content and pH of the foodstuff. However, sourness is a sensory modality that represents the perception of that acidity and it is not necessarily relate with the food pH, since it can be modify by other variables as for example sweetness (Stampanoni, 1993). Thus, it is possible to change the perception of sourness just by playing with the sweetness perception. On this line, it is understandable the effect that sweet music exerted on decreasing of sourness perception.

It is also worth to mention that although the sour music had exerted a significant effect on the increase of the perceived intensity of the sour taste of the dessert, it also had a slight influence on the decrease of sweetness perception, when compared with silence condition, reinforcing this potential modulating effect in opposite tastes.

With this results, one could imply that crossmodal studies could not only be focused on congruent correspondence between different modalities, like a specific congruent music impact on the same specific taste food, but the effect on the opposite tastes could also be considered. This approach could be extrapolated to other modalities besides auditory modality.

It is not clear why the musical congruency had a crossmodal correspondence in sour perception but not in sweet perception, where it could be expectable to be stronger. However, some speculative possibilities may be hypothesized.

One possible reason for this fact could be the high sweetness of the dessert, confirmed by the total soluble solids content measured (above 30 Brix degrees), Consequently, the participants perceived the dessert as sweeter than sour regardless the auditory stimuli to which they were exposed. This could mean that, due to the high degree of sweetness, the changes due to the auditory stimuli were not perceived. The effect of the auditory stimuli on taste was more difficult to perceive for the sweet taste than for the sour taste, which was not so strong (pH 5,2).

The fact that the gustatory stimuli was a dessert could also be a reason why sweet perception was not enhanced by sweet music. The name of food might influence the perception of its taste/flavour by building up an expectation, that captures people's attention and therefore focus/bias their perception (Schifferstein, 2001; Spence & Piqueras-Fiszman, 2014; Yeomans, Chambers, Blumenthal, & Blake, 2008). As participants were aware that they would be tasting a dessert, and usually this kind of food is associated with sweet taste, it can be plausible to consider they were expecting already to feel the sweetness, what could have affected the perception of this taste and jeopardized the influence played by the sweet music.

Another possibility that could be raised is related with the fact that people in general can be more familiarized with both sweet music and sweet taste. Besides a natural appetence for enjoying sweet food and its strong presence in food habits (Spence & Piqueras-Fiszman, 2014), it is also more likely that background music during food consumption is mainly “sweet music” than “sour music”, namely in restaurants and bars. Thus, a possible habituation could make participants less sensitive to differences in the sweet perception, than differences in sour perception.

4.3.3.1.1. Comparison with focus group

Comparing these results with those of the focus group, it is possible to see that although the majority of people in both groups find the dessert sweeter than sour, the perception of basic tastes with different auditory stimuli was remarkably different. On the focus group the auditory stimuli had a substantial influence in basic tastes perception, being this effect congruent with the crossmodal correspondence described in the literature between taste and music.

In the focus group, the effect of the musical congruency influence was quite evident regarding the sweet and sour basic tastes, since the sweetness perception of the dessert was enhanced while listening to the sweet musical pieces and the sourness perception was enhanced while listening the sour musical pieces. Moreover, the previously referred impact in decrease of the intensity of the opposite taste perception, reinforcing a more embracing music influence in taste perception, in both perspectives.

The difference of results for the focus group and sensory analysis can have an explanation related with the profile of the participants. An hypothesis that can be considered is the fact that although everyone, to some extent, has the ability to create mappings between auditory and gustatory stimuli, the role of past experiences with sound and music, embodied by musical training and professional experience in the field, could be responsible to increase the ability to associate sounds with corresponding tastes (Guetta & Loui, 2017). This ability could be the reason for the increased influence in perception for the focus group participants.

Other fact that should be considered, besides the greater musical sensitivity, is that the musicians on focus group were aware that the study aim was to understand the influence of music in taste perception. Thus, they were more focused on music and paid more attention to this variable when they were tasting the dessert, which did not happen in the sensory tests where participants did not know that the background music was the influential factor being evaluated.

4.3.3.2. Creaminess

According to literature, in general musical attributes that are congruent with creaminess are also related with sweetness (Carvalho et al., 2017; Knöferle & Spence, 2012). The musical patterns of sweet music as the consonance (melodic and/or harmonic), *legato* articulation, low discontinuity (Carvalho et al., 2017) and the soft sound intensity, could be associated with low acoustical roughness (Knöferle & Spence, 2012; Mesz et al., 2011) and therefore it might be considered congruent with creaminess (Knoeferle et al., 2015). Thus, it would be expectable that sweet music would increase the creaminess intensity in the dessert's texture (Carvalho et al., 2017), what was not verified. On the other hand, dissonance, loudness and high discontinuity of sour music could be associated with high acoustical roughness (Carvalho et al., 2017; Knoeferle et al., 2015; Knöferle & Spence, 2012). Hence, it could be plausible that sour music might have the effect of decreasing the creaminess intensity perception of the dessert, what also was not confirmed. In fact, although without statistical significance, the results showed that it was in the silence condition that dessert was considered creamier. Regarding auditory stimuli, unpredictably, the dessert was rated creamier with sour music than with sweet music. A relation between sweetness and creaminess perception, was however encountered regardless of the music stimuli. Participants rated the dessert creamier when they perceived the dessert as sweeter. Participants perceived the dessert as sweeter in the silence condition and this was the one with higher perceived creaminess as well. Even for sour and sweet condition the creaminess followed the same pattern, where sweeter perception is related with creamier perception, although according to the correlation matrix (Table 5.2), this is not a strong correlation (R=0,113).

It is also important to mention that a positive and moderate correlation was found between texture and creaminess, implying that the creamier participants rated the dessert, more pleasant they considered the texture.

The soundtrack was chosen regarding taste association. The choice and validation by the focus group did not have in consideration creaminess. However, as a match between sweetness and creaminess or sourness and roughness related with music stimuli was referred in the literature (Bronner et al., 2012; Carvalho et al., 2017; Knöferle & Spence, 2012), it was decided in the present study to evaluate the influence of the musical background in the perceived creaminess.

In future researches it could be useful to choose a specific soundtrack more focused on the creaminess match to better understand any existing correlations. It could also be interesting to study the correlation between sweetness and creaminess perception, regardless of the music stimuli, in order to better understand if this pattern is observed in a consistent way.

4.3.3.3. Suggestions for future work and methodology improvement

Using human perception as a research target always involves subjectivity as a challenge. If on one hand the participants' individuality and subjectivity is an interesting variable that enriches this kind of studies, on the other hand it is a complex issue that can hinder the understanding about what truly drives participants' responses (Spence & Piqueras-Fiszman, 2014). Every person perceived the dessert in a particular way and, in spite of the existence of some pattern in participants' response, a large intensity values range for the basic tastes and creaminess was observed.

The subjectivity regarding the intensity perceived for the attributes in sensory analysis can be a consequence of differences in the physiology of senses. Taste, for instance, is, undoubtedly, the sense with the largest individual differences regarding the distinct number of gustatory receptors among people (Shepherd, 2011; Spence & Piqueras-Fiszman, 2014). It is also important to refer that different exposition and habituation to certain basic tastes can alter people's sensitivity to certain food stimulus (Crisinel & Spence, 2010). This could be a plausible source for the variability in the intensity perception.

In this regard, although the number of participants did not allow it, it would be insightful to analyse results at an individual level to better understand the extent of the subjectivity effect on attributes perception rating. That would make possible a one by one analysis about each personal changes on the sensory attributes rating while listening the different auditory stimuli.

It is also important to point out that sometimes the problem can be to measure with accuracy in an intensity analysis what people is actually perceiving. To reinforce this factor, it was found that the results would not follow the same pattern for all the attributes if the excluded participants were considered. This would also affect the statistical results since no statistical significance would be observed. This highlights the importance of testing the ability to recognize basic tastes in this kind of experiments. The fact that such a difference in results with outliers participants was observed, also reinforce the importance of training participants and promote familiarization with the scale in order to have more accurate results, especially in a discriminative analysis task. (Stoer, Rodriguez, & Civille, 2002).

As happened with the focus group, some participants were very surprised when, after the end of the experiment, they were informed about the study aim and that the same dessert was served throughout the experiment, being the music the only changeable element. Although this particular feedback was not asked for, some participants felt the will to share it. This feedback made us wondering about how useful could have been to include qualitative data to enrich the study. In future researches, a meeting with participants after each session could be promoted in order to understand their feelings and their qualitative perception regarding the experiment. It was pretty clear that music exerted an influence, just by the simple fact that the same dessert was rated in a different way with different auditory stimuli.

Bearing in mind that music can influence discriminative and hedonic responses to food sensory attributes, subjective evaluations of music are critical to comprehend how music interact with taste (Kantono et al., 2016). That being said, it might be valuable in future researches a prior assessment concerning the nature of the relationship between participants and the music, namely the familiarity and preferences regarding the musical repertoire chosen for the experiment (Spence et al., 2013). Even not knowing the musical pieces, it is likely that participants who enjoy classic music could be more sensitive to the music effect in this experiment. Moreover, the previous musical expertise and contact with some musical instrument, even in an amateur way, could might be an influential factor. More researches should also be conducted in order to explore the role of culture, location, learning and memory in crossmodal matches (Knoeferle et al., 2015; Knöferle & Spence, 2012; Spence, 2011).

In the future, to reach a more ecological validity, the subjective factors and preferences regarding participants' individuality should be considered as a plausible mediating factor for these crossmodal matches between music and taste (Knöferle & Spence, 2012; Spence, 2011; Wang (Janice) & Spence, 2015). These crossmodal mappings could also be influenced by the individual preference of gustatory and auditory stimuli (Guetta & Loui, 2017).

This study should be replicated with a larger number of trained participants, and a more extensive repertoire of music for each taste (Kontukoski et al., 2015), in order to overcome/minimize the subjectivity issue and confer strength to the results. It would also be interesting to use a different food stimuli composed with the same basic tastes to understand the effect of the food itself in the results obtained.

In the future it might also be useful to include in this experiment the other basic tastes (salty and bitter) to develop a larger knowledge regarding the influence of music in all tastes perception. Additionally, different basic tastes combinations could be made, with the appropriate food stimuli.

The music selected for this study took in consideration the musical patterns for sweetness and sourness (Bronner et al., 2012; Crisinel et al., 2012; Crisinel & Spence, 2009, 2010; Crisinel & spence, 2010; Knöferle & Spence, 2012; Kontukoski et al., 2015; Mesz et al., 2012, 2011; Wang et al., 2015). Despite this common pattern across the musical pieces, it is not possible to rule out the subjectivity of the musicians that took part in musical selection and validation process. However, regardless the specific musical pieces chosen, subjectivity would always be a variable.

The sounds of the “sweet” and “sour” music were produced by different instruments. Although this difference in timbre had been intended to evoke more effectively the matched basic tastes, since piano timbre may be associated with sweetness and violin with sourness, this might effect on how consumers map sounds onto tastes (Crisinel & Spence, 2010), becoming a potential confounder (Knöferle & Spence, 2012; Kontukoski et al., 2015).

One could also argue that the music excerpt used could also influence the results. The music was not used in their entireness, as it was turned off when all participants finished the tasting experience. This fact could suggest that the sampled was not the ideal or most informative parts for matching with the desired tastes. It also has to be considered that people ate the dessert with different speed and as result with different parts of the music playing in background. This could also influence the perception if the music part corresponded to a less appropriate excerpt for the taste matching. However, it is important to mention that the decision to limit the length of each sound sample had the intuit of avoiding participants fatigue (Wang et al., 2015). Although there are some differences across the music length they were not consider enough to bias the overall perception.

Perhaps the music should have been introduced a while before the precise moment when participants started eating the dessert, in order to let them more comfortable with the auditory stimuli and allow gradually input the gustatory stimulus. Probably if this was done, it could be easier for participants to notice the sensory attributes because they did not need to process all the new information at once. Thus, this could have generated less confusion and a more focused sensory analysis.

In order to achieve an enhancement of external validity in future researches, it could be interesting to increase the complexity of the gustatory stimulus, for instance, a typical meal of an everyday situation (Kantono et al., 2016).

It is also worth highlighting that the musical pieces chosen for this experiment were relatively simple in terms of their musical composition. It might be interesting in future, in interest of external validity, to conduct a similar study with a more complex sound stimulus, with more instrumental layers and/or more sound effects, in some way more aligned with real food consumption environments (Carvalho et al., 2017; Kantono et al., 2016).

Regarding experimental procedure, it is important to mention that in this growing field of research a well-controlled experiment, involving a maximal accurate measurement of the participants' experience is crucial (Spence & Piqueras-Fiszman, 2014). These studies could be conducted both in laboratory or in the real world. The present one was conducted in laboratory context in order to eliminate all the unrelated variables, so participants could focus only on factors with interest for the study, ensuring that some change in participants' response could be attributable to the stimuli introduced. However, this kind of studies could be criticized for their lack of ecologic validity, since participants are sitting alone without facing each other, with no background noise or any other distraction, what does not correspond to the natural atmosphere where food usually is consumed. In this regard, could be interesting repeat this experiment using a more real world setting such a cafe or a restaurant and to compare the results (Kantono et al., 2016; Spence & Piqueras-Fiszman, 2014). However, in a real world context, although its ecologic validity, it is important bear in mind the unavoidable lack of control over other key variables that might be expected to have an effect on a participants' responses (Spence & Piqueras-Fiszman, 2014).

Most studies that have been published regarding perceptual influences of sound and taste used what is known as a within-participants experimental design (Spence & Piqueras-Fiszman, 2014). As in those studies, this study followed the experimental design mentioned, in which each participant was exposed to each and every one of the conditions. This brings strength to research since it allows to dismiss any individual differences between participants as the cause of any effect presented. This would not be ensured in a between-participants experimental design because there is the possibility that participants in each group were not matched in all possible regards.

Although all participants had experienced all test conditions, it should be highlighted that they did not experience them with the same order because of the randomization required. It might be interesting to try to understand the order effect on dessert perception and assess its influence extent. The ability that music has to induce positive and negative emotions and to change the mood, allied with the importance of the mood as cue to judgments making, (Spence, 2017; Spence & Piqueras-Fiszman, 2014) could imply that the music order regarding each test condition could be considered a possible bias in participant perception for the next one.

Although this study focus on the influence of the music in taste perception, one can wonder if these relationships can be bi-directional, and how do what people eat affect the perception of the music they are listening to at that moment.

5. CONCLUSION

In last years, a growing body of researches has evidenced a huge impact of the hearing sense in the perception of food experiences. The background soundscapes, and particularly music, can alter not only choices, but also the sensory perception, either discriminative or hedonic, of a food experience. The auditory properties of a musical piece could be matched in a congruent manner with the basic tastes, altering the way consumers perceive, respond and remember the sensory attributes and the overall experience. Bearing in mind this powerful idea, the present study was developed intending to explore the influence of background music in the tasting experience and the crossmodal interactions that could occur between gustatory and auditory stimulus.

Regardless of the strength of the results it was found that people did not perceived the same dessert exactly in the same way when exposed to different music stimulus, what suggests by itself the music influence in the tasting experience. Furthermore, it was observed that crossmodal correspondences between music and taste were stronger regarding sour taste where a significant effect was felt. Sweet music, in opposite, did not evoke the sweet taste of the dessert. However, it decreased the intensity of sour taste in the dessert what could suggest a different approach to crossmodal correspondences between music and taste.

In general these findings might have a great potential on design and building of new multisensory gastronomic experiences (Kontukoski et al., 2015). Music is a special ingredient that could be thoughtfully matched with a gustatory stimulus in order to enhance consumer experiences. Being aware of the crossmodal associations between sound and taste, the existing knowledge can be applied by food businesses and restaurant entrepreneurs in marketing products and to enhance consumer experience (Crisinel & Spence, 2010; Guetta & Loui, 2017; Spence, Shankar, & Blumenthal, 2011). A multidisciplinary approach, involving science and art working together, could deliver more immersive and memorable food experiences capable of engaging all senses.

Besides the crucial role in the creation of more memorable and valuable food experiences, these achievements could also bring some improvements in terms of health. Music could be played to patients with impairments on gustation in order to highlight some specific taste perception and consequently increase the eating enjoyment (Crisinel & Spence, 2009). Specially regarding patients with restrictions on sugar content, these “perceptions tricks” could be very helpful, since it might be possible to alter the perception of sweetness, making sour food taste sweeter without adding sugar. It could be also possible to decrease the sour perception without adding sugar to counterbalance.

Taking into account the emotional valence linking as presented on this study results, one could consider the possibility of increasing the consumption of healthier but unpleasant foods by combining it with a pleasant music on the background (Kantono et al., 2016).

In a world willing for astounding and stimulating experiences, this could be a step further to reinforce the congruency and pleasure of multisensory experiences.

I always find myself amazed about the food experience and all the subjective variables that can change it, thus this dissertation represents a small materialization of this endless passion and a step further in the willingness to achieve a more scientific approach regarding probably the most artistic, mysterious and complex expression in the world, the human perception. This was a deconstruction work, in opposition to what could be thought, when we talk about food and human beings there are no singular response and no one feels the same thing in the same way under the same inputs. It was intended to explore the subjective nature of the way all stimuli are perceived and interpreted and how they interfere with each other to create what can be called ‘the experience’. The beauty of human perception diversity, and its ability to transform each food experience in a unique one, was simultaneously the most magical and challenging issue. Although all effort was made to perform this study in the best way possible (with the resources and means available), these kinds of researches ideally should have a bigger number of participants and these should be well trained to identify different patterns of sweetness and sourness, in order to obtain more reliable findings. However, even bearing in mind its limitations, this work was an invaluable experience of learning and growing, and it represents a small but real step in a path of curiosity and passion about food perception.

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7. ANNEXES

ANNEX A – Passion Fruit Mousse Recipe

INGREDIENTS	PREPARATION
. 3 packages of frozen passion fruit pulp (300 g); . 3 colourless gelatine sheets (6 g); . 1 can of condensed milk (400 g); . 2 packages of cream (400 g).	1. Heat the passion fruit pulp (60-70 ºC) and hydrate the gelatine leaves in cold water. 2. Remove the water excess from the gelatine and dissolve it in the heated passion fruit pulp. 3. Reserve and let cool. In the meantime, lightly whip the cream (it shouldn´t be as firm as Chantilly) 4. Using a wire whisk, blend the condensed milk with the passion fruit pulp. 5. Make sure that the previous preparation is completely cool and then gently incorporate the whipped cream. 6. Transfer the preparation to disposable cups and put in the refrigerator at least 3 hours before serving.

ANNEX B – Focus Group Script

Focus group Aim: Musical pieces' choice and validation for the study.

Focus group steps:

- **<u>Introduction</u>**

Good evening everyone and welcome to our session. Thank you for having accepted to be part of this focus group that will give crucial information for my thesis project development. The aims are to understand if and how music influences the perception of a food experience. In this focus group we will discuss, choose and validate the musical pieces that latter will be used in the sensory tests to get the results.

A focus group is a social research method, especially used for the analysis of subjective themes that raise divergent opinions, where the sharing, discussion and clarification of points of view and ideas is provided. That being said, it is important be aware that there are no right or wrong answers but rather differing points of view. Please feel completely free to share your points of view even if they differ from those expressed by others. This enriches the session, that should be conducted with all mutual respect. All of you should share your opinions, speaking one at a time.

If you don't mind, I will record the session because I don't want to miss any important comment. However, you may be assured of complete confidentiality.

The session should not take you more than 2 h, and my role as moderator will be to guide the discussion. Before the beginning, I ask you to introduce yourselves, telling us your first name and your relationship with music (professional or enthusiastic).

- **<u>Discussion</u>**

<u>Route</u>

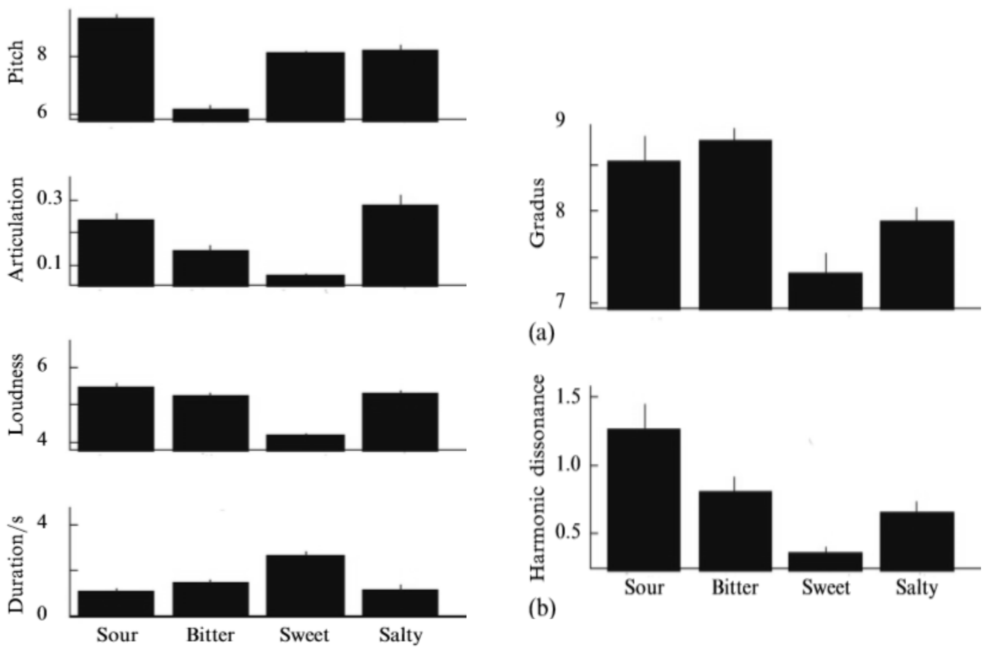
1) have you ever heard of an association between music and basic tastes perception (sweet, salty, sour and bitter)? Have you ever described a music using a basic taste? If so, which musical characteristics and tastes were associated? (Free association of words that describe it)

2) There are some specific characteristics of musical parameters that have being associated as intensifiers of basic tastes perception. Before talking about them, we will do an experiment. I am going to give you a passion fruit mousse, that has two basic tastes, sweet and sour. (These will be the tastes studied in this research project). And you will taste it in silence and with different musical pieces. I ask you, for each moment, to mark at any part of the line presented in the evaluation sheet provided, the perceived intensity for each one of two tastes. Take the numbers as reference: 1=not sweet/sour 2=slightly sweet/sour 3=medium 4=moderately sweet/sour 5=very sweet/sour. However, you can mark the perceived intensity at any part of the line.

3) Have you noticed any difference in sweet and sour perception in each different moment? How was that difference? In which moment the sweet perception was more intense? And the sour perception? Can you enumerate each moment in a decrease order of intensity for each one of the tastes?

4) The musical pieces that you just heard were chosen take into account the results of the studies relating music with basic tastes:

<u>Sour</u> –high-pitched, fast, articulated, and dissonant;
<u>Bitter</u> – low-pitched and low articulated (*legato*), with some dissonant attributes;
<u>Sweet</u> – medium-high-pitched, consonant, slow, soft, low articulated (*legato*) and low loudness;
<u>Salty</u> – medium-high-pitched, fast and high articulated (*staccato*)



(Reading, interpretation and discussion of the graphics by the group – comparison between sweet and sour)

5) Two musical pieces were selected for the sweet taste and two other musical pieces for the sour taste. Let's heard them again and I ask you to identify which one them are related with the sweet and sour tastes, based on relation just described. Is it congruent with your perception when tasting the dessert?

6) Among the sweet musical pieces, taking into account the musical parameters (pitch, articulation, loudness, duration and dissonance) and your perception when tasting the passion fruit mousse, which one do you consider more appropriate for the sensory tests?

7) Among the sour musical pieces, taking into account the musical parameters (pitch, articulation, loudness, duration and dissonance) and your perception when tasting the passion fruit mousse, which one you consider more appropriate for the sensory tests?

8) Which volume do you suggest for each musical piece during the sensory tests?

- **<u>Conclusion</u>**

After discussion and sharing of your points of view, we were able to choose and validate the musical pieces that will be used in sensory tests. For the sweet taste will be used the music: "…" and for the sour taste will be used the music: "..."

Thank you all for your presence and participation in this focus group, your contribution was undoubtedly essential.

ANNEX C - Focus Group Sensory Analysis Form

Sensory Analysis Form

Name:____ Date_____________________

Gender:____________________ Age: ( ) < 25 ( ) 25 - 34 ( ) 35 - 45 ( ) 46 - 55 ( ) >55

Please, **TASTE** each sample and mark the perceived intensity of basic tastes at any part of the line. Note that the intensity increase from left to the right. **Take the numbers as reference:** 1=no sweet/sour 2=slightly sweet/sour 3=medium 4=moderately sweet/sour 5=very sweet/sour. However, you can mark the perceived intensity at any part of the line.

Silence

Sweet:

1 2 3 4 5

Nothing sweet — Very sweet

Sour:

1 2 3 4 5

Nothing sour — Very sour

Music 1

Sweet:

1 2 3 4 5

Nothing sweet — Very sweet

Sour:

1 2 3 4 5

Nothing sour — Very sour

Music 2

Sweet:

1 2 3 4 5

Nothing sweet Very sweet

Sour:

1 2 3 4 5

Nothing sour Very sour

Music 3

Sweet:

1 2 3 4 5

Nothing sweet Very sweet

Sour:

1 2 3 4 5

Nothing sour Very sour

Music 4

Sweet:

1 2 3 4 5

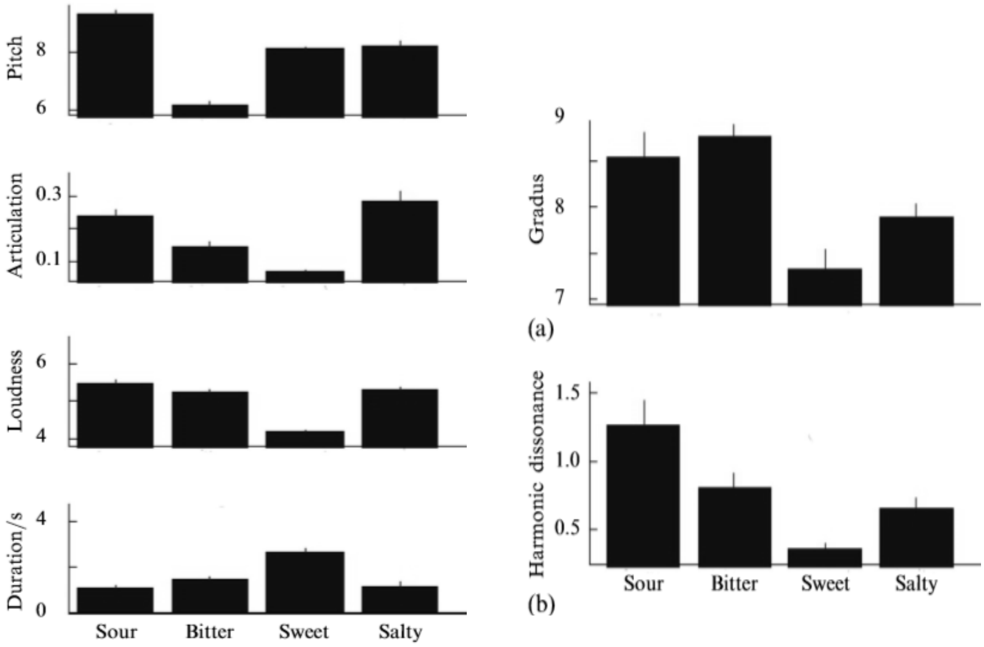
Nothing sweet Very sweet

Sour:

1 2 3 4 5

Nothing sour Very sour

ANNEX D – Graphics by Mesz *et all* (2011) regarding the relation between relevant musical parameters and basic tastes



ANNEX E – Musical Sheets

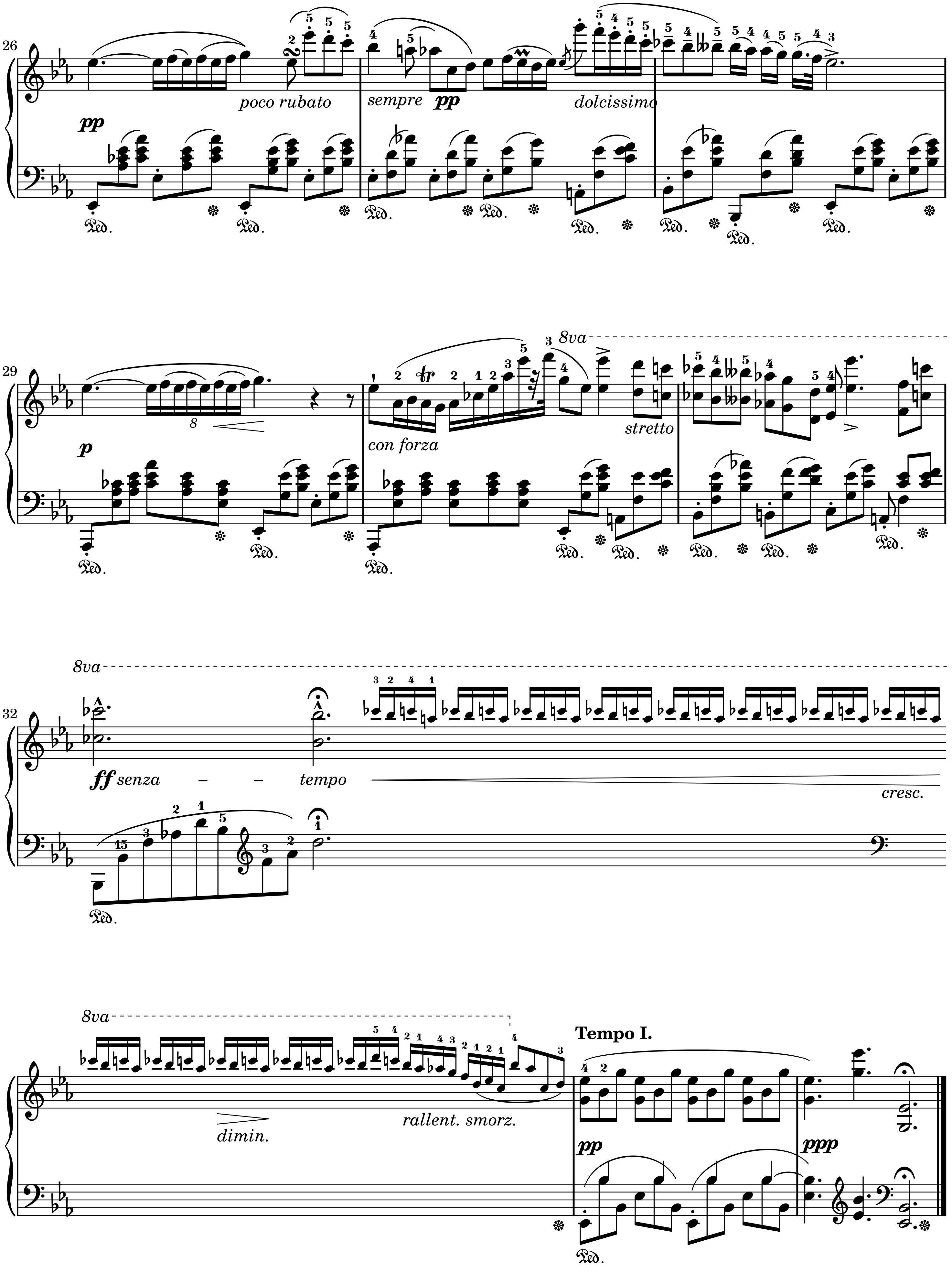
A M.me Marie Pleyel

Nocturne

Frédéric Chopin

Op. 9 N. 2

Tempo I.
sf
p
cresc.
Ped.
(f)
(più p)
f
poco rall.
Tempo I.
Coda


poco rubato
sempre pp
dolcissimo
8va
con forza
stretto
ff senza – – tempo
cresc.
dimin.
rallent. smorz.
Tempo I.
pp
ppp


Andante.
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Fagotti.
Corni in F.
Pianoforte.
Violino I.
Violino II.
Viola.
Violoncello e Basso.
Con Sordino
Con Sordino
Con Sordino


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3

CAPRICE No. 24

NICCOLO PAGANINI
Arranged by JOHN WILLIAMS

THEME
Non troppo presto

First publication for sale 1979, United Kingdom

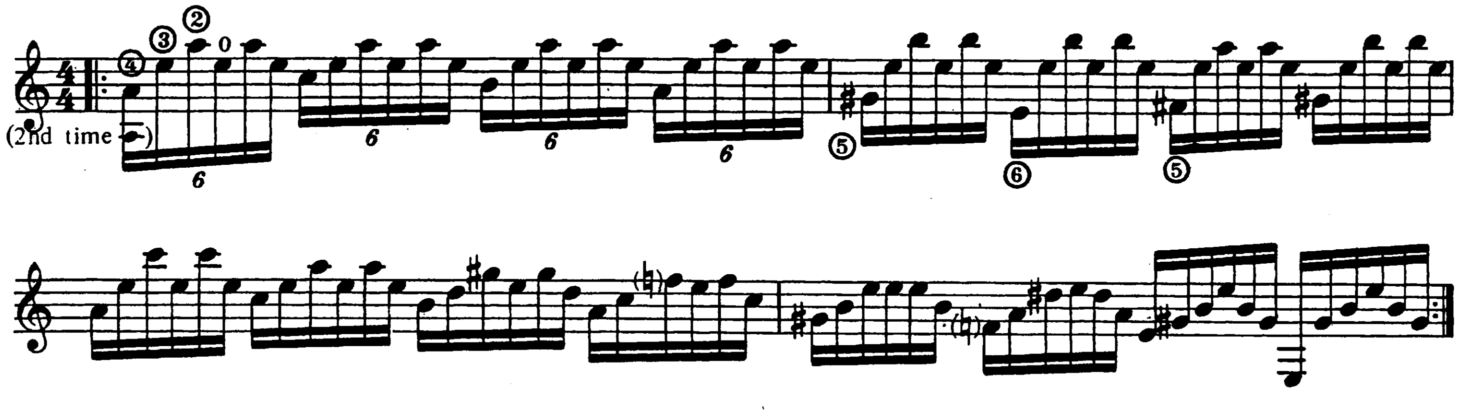
Printed in England


Var. III
(8)
Var. IV
Var. V

Var. VI

Var. VII

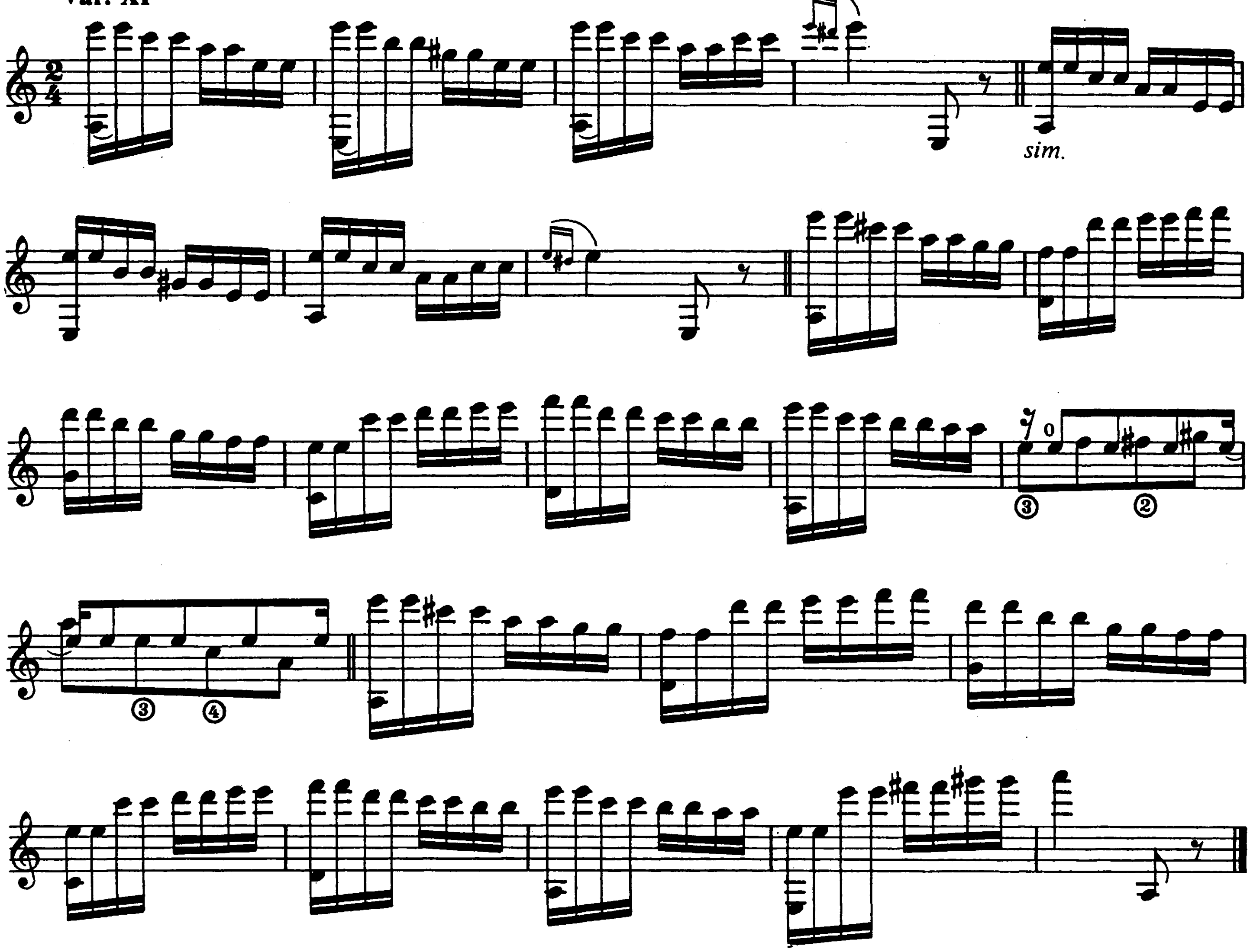
Var. VIII



Var. IX

Var. X

Var. XI



Var. XII

Finale

Flight of the Bumble-Bee

N. Rimsky-Korsakoff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Tba.
Timp.
Vln. I
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C. A.
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Tpt.
Tbn.
Tba.
Timp.
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ANNEX F – Informed Consent

Informed consent

You are being invited to participate as a volunteer in a research test for the dissertation project of Joana Campinho, a MSc student in Gastronomical Sciences at Faculdade de Ciências e Tecnologia - Universidade Nova de Lisboa (FCT /UNL) and Instituto Superior de Agronomia - Universidade de Lisboa, under the supervision of Professor Paulina Mata (FCT / UNL).

This will be a voluntary activity and therefore unpaid. However, you will be contributing to the acquisition of new scientific knowledge. Your participation in this study is not mandatory and you can give up at any time.

All data collected are confidential and used strictly to obtain the results of this study.

If you agree to participate, you will pass by several different food experiences, at room 218 of the Chemistry Department at FCT / UNL, with a global estimated duration of 30 minutes.

If you agree to be part of this study, we ask you to sign below:

____

Thank you very much for your participation.

ANNEX G – Recruitment Form

PARTICIPANT'S PROFILE

Name ____ Date ________________

Gender:________________ Age: ( ) < 25 ( ) 25 - 34 ( ) 35 - 45 ( ) 46 - 55 ( ) >55

Do you have any food intolerance/ allergy?

( ) Yes ( ) No If yes, which?______________________________

Do you usually eat passion fruit or passion fruit products?

( ) Yes ( ) No

Do you have any impairment in the following senses?

Taste ( ) Yes ( ) No

Smell ( ) Yes ( ) No

Hearing ( ) Yes ( ) No

BASIC TASTES RECOGNITION

Please, **TASTE** each sample from left to right and identify the taste as sweet, bitter, sour, salty or neutral. Please register in the table below the code of the sample and the taste identified. There may be samples containing only water.

Sample	**Description**

ANNEX H – Scale Familiarization Form

Scale Familiarization Form

Name:____ Date____________________

Gender:___________________ Age: ( ) < 25 ( ) 25 - 34 ( ) 35 - 45 ( ) 46 - 55 ( ) >55

Please, **TASTE** each sample and mark the perceived intensity of basic tastes at any part of the line. Note that the intensity increase from left to the right. **Take the numbers as reference:** 1=no sweet/sour 2=slightly sweet/sour 3=medium 4=moderately sweet/sour 5=very sweet/sour. However, you can mark the perceived intensity at any part of the line.

Sample no__________

Sweet: 1 2 3 4 5

Nothing sweet Very sweet

Sample no__________

Sweet: 1 2 3 4 5

Very sweet

Nothing sweet

Sample no__________

Sour: 1 2 3 4 5

Nothing sour Very sour

Sample no__________

Sour: 1 2 3 4 5

Nothing sour Very sour

ANNEX I- Sensory Analysis Form

Name:____ Date____________________

Gender:___________________ Age: ( ) < 25 ( ) 25 - 34 ( ) 35 - 45 ( ) 46 - 55 ( ) >55

Product: Dessert Sample nº:_________________

You are receiving a dessert sample. Please, **OBESERVE** and **SMELL** the sample and indicate, by circling the corresponding number, how pleasant or unpleasant would you rate the attributes below:

APPEARANCE	**COLOUR**	**AROMA**
9 = Extremely pleasant	**9** = Extremely pleasant	**9** = Extremely pleasant
8 = Very much pleasant	**8** = Very much pleasant	**8** = Very much pleasant
7 = Moderately pleasant	**7** = Moderately pleasant	**7** = Moderately pleasant
6 = Lightly pleasant	**6** = Lightly pleasant	**6** = Lightly pleasant
5 = Neither pleasant, nor unpleasant	**5** = Neither pleasant, nor unpleasant	**5** = Neither pleasant, nor unpleasant
4 = Lightly unpleasant	**4** = Lightly unpleasant	**4** = Lightly unpleasant
3 = Moderately unpleasant	**3** = Moderately unpleasant	**3** = Moderately unpleasant
2 = Very much unpleasant	**2** = Very much unpleasant	**2** = Very much unpleasant
1 = Extremely unpleasant	**1** = Extremely unpleasant	**1** = Extremely unpleasant

Please, **TASTE** the sample and mark the perceived intensity of basic tastes at any part of the line. Note that the intensity increase from left to the right. **Take the numbers as reference:** 1=nothing sweet/sour 2=slightly sweet/sour 3=medium 4=moderately sweet/sour 5=very sweet/sour. However, you can mark the perceived intensity at any part of the line.

Sweet:

1 2 3 4 5

Nothing sweet — Very sweet

Sour:

1 2 3 4 5

Nothing sour — Very sour

Regarding **creaminess**, please mark the perceived intensity at any part of the line. Note that the intensity increase from left to the right. **Take the numbers as reference:** 1=nothing creamy 2=slightly creamy 3=medium 4=moderately creamy 5=very creamy. However, you can mark the perceived intensity at any part of the line.

1 2 3 4 5

Nothing creamy Very creamy

Please, indicate, by circling the corresponding number, how would you rate the attributes below and the overall experience:

TEXTURE	**FLAVOUR**	**OVERALL EXPERIENCE**
9 = Extremely pleasant	**9** = Extremely pleasant	**9** = Like extremely
8 = Very much pleasant	**8** = Very much pleasant	**8** = Like very much
7 = Moderately pleasant	**7** = Moderately pleasant	**7** = Like moderately
6 = Lightly pleasant	**6** = Lightly pleasant	**6** = Like lightly
5 = Neither pleasant, nor unpleasant	**5** = Neither pleasant, nor unpleasant	**5** = Neither like, nor dislike
4 = Lightly unpleasant	**4** = Lightly unpleasant	**4** = Dislike lightly
3 = Moderately unpleasant	**3** = Moderately unpleasant	**3** = Dislike moderately
2 = Very much unpleasant	**2** = Very much unpleasant	**2** = Dislike very much
1 = Extremely unpleasant	**1** = Extremely unpleasant	**1** = Dislike extremely

Ficha de análise sensorial

Nome:____ Data____________________

Género:___________________ Idade: ( ) < 25 ( ) 25 - 34 ( ) 35 - 45 ( ) 46 - 55 ( ) >55

Produto: Sobremesa Amostra nº:_________________

Recebeu uma amostra de sobremesa. Por favor, **OBSERVE** e **CHEIRE** a amostra e indique, circulando o número correspondente, quão agradável ou desagradável a classificaria relativamente aos atributos abaixo:

APARÊNCIA	**COR**	**AROMA**
9 = Extremamente agradável	**9** = Extremamente agradável	**9** = Extremamente agradável
8 = Muito agradável	**8** = Muito agradável	**8** = Muito agradável
7 = Moderadamente agradável	**7** = Moderadamente agradável	**7** = Moderadamente agradável
6 = Ligeiramente agradável	**6** = Ligeiramente agradável	**6** = Ligeiramente agradável
5 = Nem agradável, nem desagradável	**5** = Nem agradável, nem desagradável	**5** = Nem agradável, nem desagradável
4 = Ligeiramente desagradável	**4** = Ligeiramente desagradável	**4** = Ligeiramente desagradável
3 = Moderadamente desagradável	**3** = Moderadamente desagradável	**3** = Moderadamente desagradável
2 = Muito desagradável	**2** = Muito desagradável	**2** = Muito desagradável
1 = Extremamente desagradável	**1** = Extremamente desagradável	**1** = Extremamente desagradável

Agora, **PROVE** a amostra e marque em qualquer parte da linha correspondente aos gostos básicos, a intensidade percebida. Note que a intensidade aumenta da esquerda para a direita. **Tome os números como referência**: 1=nada doce/ácido 2=ligeiramente doce/ácido, 3=médio, 4=moderadamente doce/ácido, 5=muito doce/ácido. No entanto pode marcar a intensidade percebida em qualquer parte da linha.

Doce:

1 2 3 4 5

Nada doce Muito doce

Ácido

1 2 3 4 5

Nada ácido Muito ácido

Relativamente à **cremosidade**, marque em qualquer parte da linha abaixo a intensidade percebida. Note que a intensidade aumenta da esquerda para a direita. **Tome os números como referência**: 1=nada cremoso 2=ligeiramente cremoso, 3=médio, 4=moderadamente cremoso, 5=muito cremoso. No entanto pode marcar a intensidade percebida em qualquer parte da linha.

1 2 3 4 5

Nada cremoso Muito cremoso

Indique, circulando o número correspondente, como classificaria a amostra ainda relativamente à textura, ao sabor e à experiência no geral:

TEXTURA	SABOR	IMPRESSÃO GERAL
9 = Extremamente agradável	**9** = Extremamente agradável	**9** = Gostei extremamente
8 = Muito agradável	**8** = Muito agradável	**8** = Gostei muito
7 = Moderadamente agradável	**7** = Moderadamente agradável	**7** = Gostei moderadamente
6 = Ligeiramente agradável	**6** = Ligeiramente agradável	**6** = Gostei ligeiramente
5 = Nem agradável, nem desagradável	**5** = Nem agradável, nem desagradável	**5** = Nem gostei, nem desgostei
4 = Ligeiramente desagradável	**4** = Ligeiramente desagradável	**4** = Desgostei ligeiramente
3 = Moderadamente desagradável	**3** = Moderadamente desagradável	**3** = Desgostei moderadamente
2 = Muito desagradável	**2** = Muito desagradável	**2** = Desgostei muito
1 = Extremamente desagradável	**1** = Extremamente desagradável	**1** = Desgostei extremamente

ANNEX J – Sensory Analysis Statistic Data Focus Group

Condition	Attribute	*N*	Min	Max	Mean	Standard deviation
Silence	Sweetness	5	3,934	6,586	5,260	0,636
	Sourness	5	3,697	6,143	4,920	0,586
Music 1	Sweetness	5	6,014	8,666	7,340	0,636
	Sourness	5	2,277	4,723	3,500	0,586
Music 2	Sweetness	5	4,554	7,206	5,880	0,636
	Sourness	5	2,957	5,403	4,180	0,586
Music 3	Sweetness	5	3,694	6,346	5,020	0,636
	Sourness	5	4,697	7,143	5,920	0,586
Music 4	Sweetness	5	3,174	5,826	4,500	0,636
	Sourness	5	5,097	7,543	6,320	0,586

The values are presented in centimetres (cm).

ANNEX K – Sensory Analysis Statistic Data

Attribute	Condition	*N*	Min	Max	Mean	Standard deviation
Appearance	Sour music	49	6,754	7,368	7,061	0,155
	Silence	49	6,713	7,328	7,020	0,155
	Sweet music	49	6,856	7,471	7,163	0,155
Colour	Sour music	49	6,836	7,449	7,143	0,155
	Silence	49	6,734	7,347	7,041	0,155
	Sweet music	49	6,775	7,388	7,082	0,155
Aroma	Sour music	49	6,606	7,312	6,959	0,178
	Silence	49	6,729	7,434	7,082	0,178
	Sweet music	49	6,402	7,108	6,755	0,178
Sweetness*	Sour music	49	44,907	54,317	49,612	2,380
	Silence	49	45,050	54,460	49,755	2,380
	Sweet music	49	44,172	53,583	48,878	2,380
Sourness*	Sour music	49	39,438	50,562	45,000	2,814
	Silence	49	36,051	47,174	41,612	2,814
	Sweet music	49	30,602	41,725	36,163	2,814
Creaminess*	Sour music	49	57,958	67,879	62,918	2,510
	Silence	49	58,651	68,573	63,612	2,510
	Sweet music	49	56,774	66,696	61,735	2,510
Texture	Sour music	49	7,731	8,187	7,959	0,115
	Silence	49	7,711	8,167	7,939	0,115
	Sweet music	49	7,527	7,983	7,755	0,115
Flavour	Sour music	49	7,397	7,828	7,612	0,109
	Silence	49	7,438	7,868	7,653	0,109
	Sweet music	49	7,540	7,971	7,755	0,109
Overall experience	Sour music	49	7,373	7,811	7,592	0,111
	Silence	49	7,515	7,954	7,633	0,111
	Sweet music	49	7,515	7,954	7,735	0,111

* The values are presented in millimetres (mm).

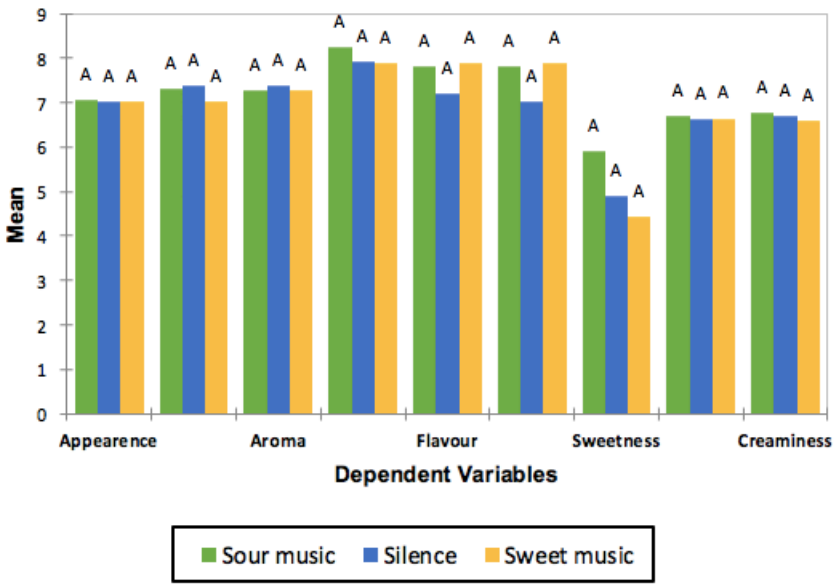
ANNEX L – Sensory Analysis Statistic Data Divided by Sweetness and Sourness Levels of Intensity

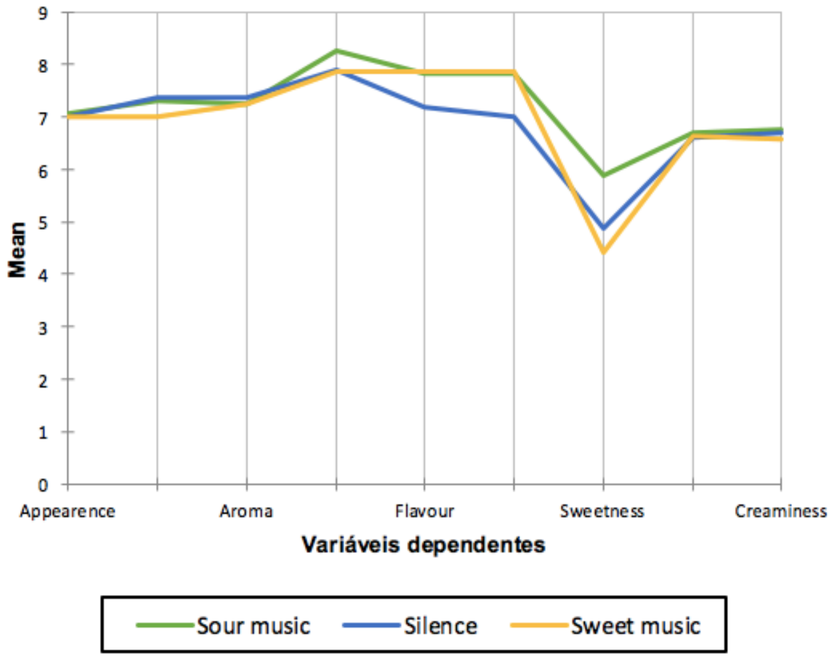
High Sourness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,395	7,730	7,063	0,328
	Silence	6,195	7,805	7,000	0,395
	Sweet music	6,056	7,944	7,000	0,463
Colour	Sour music	6,689	7,936	7,313	0,306
	Silence	6,612	8,116	7,364	0,369
	Sweet music	6,118	7,882	7,000	0,433
Aroma	Sour music	6,594	7,906	7,250	0,322
	Silence	6,573	8,154	7,364	0,388
	Sweet music	6,323	8,177	7,250	0,455
Texture	Sour music	7,904	8,596	8,250	0,170
	Silence	7,492	8,327	7,909	0,205
	Sweet music	7,385	8,365	7,875	0,240
Flavour	Sour music	7,813	0,261	7,280	8,345
	Silence	7,182	0,315	6,540	7,824
	Sweet music	7,875	0,369	7,122	8,628
Overall experience	Sour music	7,813	0,239	7,325	8,300
	Silence	7,000	0,289	6,412	7,588
	Sweet music	7,875	0,338	7,186	8,564
Sweetness*	Sour music	5,055	6,720	5,888	0,409
	Silence	3,887	5,895	4,891	0,493
	Sweet music	3,236	5,589	4,413	0,578
Sourness*	Sour music	6,389	7,024	6,706	0,156
	Silence	6,226	6,992	6,609	0,188
	Sweet music	6,188	7,087	6,638	0,221
Creaminess*	Sour music	5,866	7,659	6,763	0,440
	Silence	5,609	7,772	6,691	0,531
	Sweet music	5,319	7,856	6,588	0,623

* The values are presented in centimetres (cm).

Impact of the three experiences on the mean perception of the attributes - High Sourness

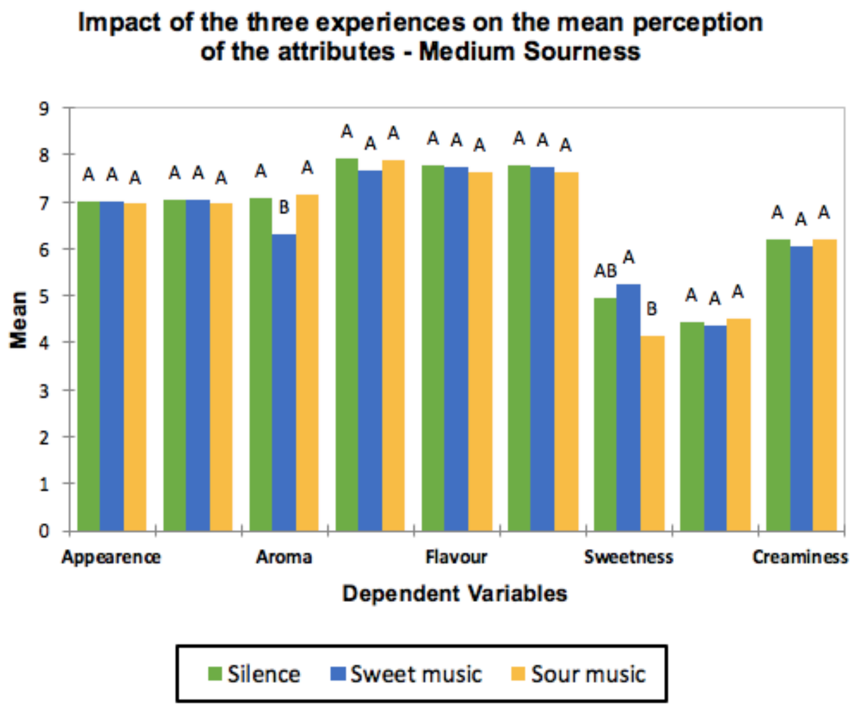


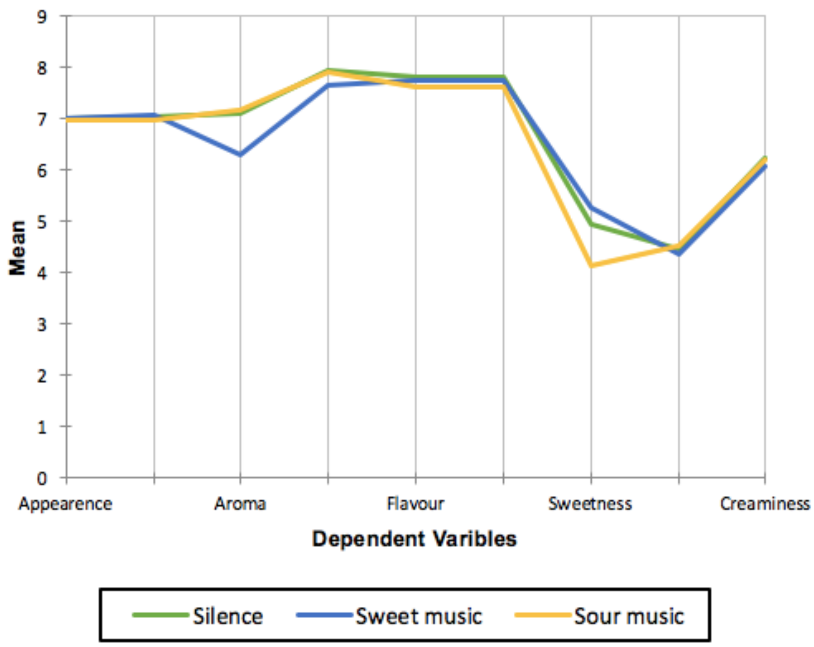


Medium Sourness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,473	7,432	6,952	0,240
	Silence	6,551	7,449	7,000	0,224
	Sweet music	6,509	7,491	7,000	0,246
Colour	Sour music	6,499	7,405	6,952	0,227
	Silence	6,618	7,465	7,042	0,212
	Sweet music	6,586	7,514	7,050	0,232
Aroma	Sour music	6,627	7,658	7,143	0,258
	Silence	6,601	7,566	7,083	0,241
	Sweet music	5,772	6,828	6,300	0,264
Texture	Sour music	7,528	8,281	7,905	0,188
	Silence	7,564	8,269	7,917	0,176
	Sweet music	7,264	8,036	7,650	0,193
Flavour	Sour music	7,619	0,138	7,344	7,894
	Silence	7,534	8,049	7,792	0,129
	Sweet music	7,468	8,032	7,750	0,141
Overall experience	Sour music	7,322	7,916	7,619	0,148
	Silence	7,514	8,069	7,792	0,139
	Sweet music	7,446	8,054	7,750	0,152
Sweetness*	Sour music	3,416	4,860	4,138	0,361
	Silence	4,275	5,625	4,950	0,338
	Sweet music	4,505	5,985	5,245	0,370
Sourness*	Sour music	4,217	4,821	4,519	0,151
	Silence	4,172	4,736	4,454	0,141
	Sweet music	4,051	4,669	4,360	0,155
Creaminess*	Sour music	5,436	6,945	6,190	0,377
	Silence	5,507	6,918	6,213	0,353
	Sweet music	5,282	6,828	6,055	0,387

* The values are presented in centimetres (cm).


Impact of the three experiences on the mean perception of the attributes - Medium Sourness
Mean
Dependent Variables
Appearence
Aroma
Flavour
Sweetness
Creaminess
A A A A A A A B A A A A A A A A A A AB A B A A A A A A
Silence
Sweet music
Sour music

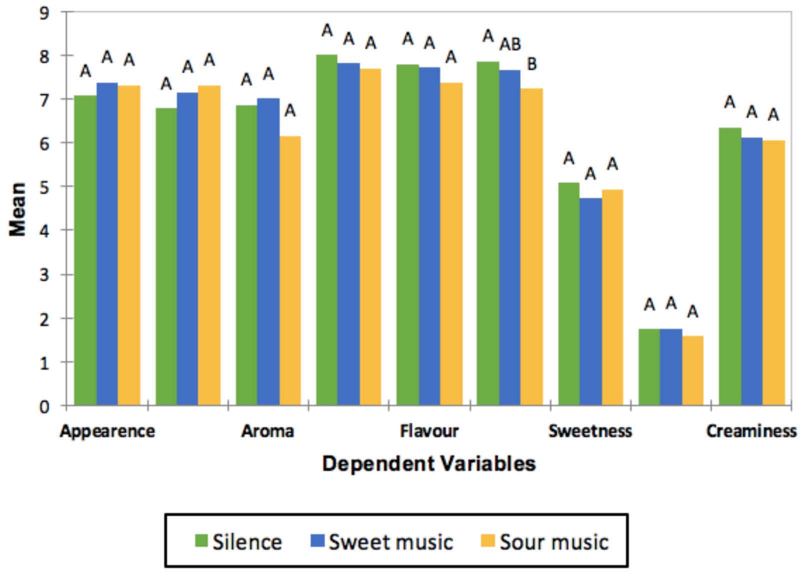

Mean
Appearence
Aroma
Flavour
Sweetness
Creaminess
Dependent Varibles
Silence
Sweet music
Sour music

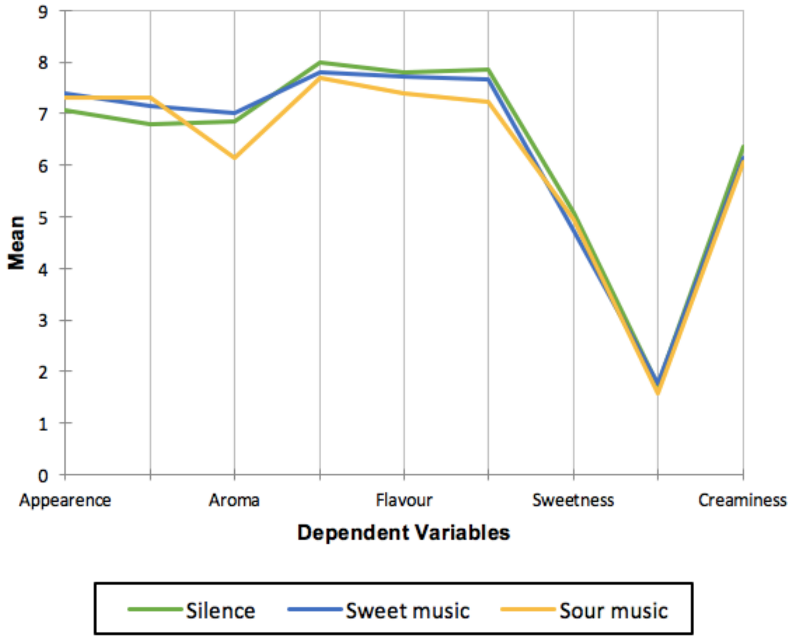
Low Sourness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,790	7,825	7,308	0,257
	Silence	6,573	7,570	7,071	0,248
	Sweet music	6,974	7,788	7,381	0,202
Colour	Sour music	6,709	7,906	7,308	0,297
	Silence	6,209	7,363	6,786	0,286
	Sweet music	6,672	7,614	7,143	0,234
Aroma	Sour music	5,460	6,848	6,154	0,344
	Silence	6,189	7,526	6,857	0,332
	Sweet music	6,454	7,546	7,000	0,271
Texture	Sour music	7,236	8,148	7,692	0,226
	Silence	7,560	8,440	8,000	0,218
	Sweet music	7,451	8,168	7,810	0,178
Flavour	Sour music	7,015	7,754	7,385	0,184
	Silence	7,429	8,142	7,786	0,177
	Sweet music	7,423	8,005	7,714	0,144
Overall experience	Sour music	6,852	7,610	7,231	0,188
	Silence	7,492	8,222	7,857	0,181
	Sweet music	7,369	7,965	7,667	0,148
Sweetness*	Sour music	4,030	5,847	4,938	0,451
	Silence	4,210	5,961	5,086	0,435
	Sweet music	4,014	5,443	4,729	0,355
Sourness*	Sour music	1,153	2,000	1,577	0,210
	Silence	1,328	2,144	1,736	0,203
	Sweet music	1,424	2,090	1,757	0,165
Creaminess*	Sour music	5,010	7,098	6,054	0,518
	Silence	5,351	7,363	6,357	0,500
	Sweet music	5,307	6,950	6,129	0,408

* The values are presented in centimetres (cm).

Impact of the three experiences on the mean perception of the attributes - Low Sourness



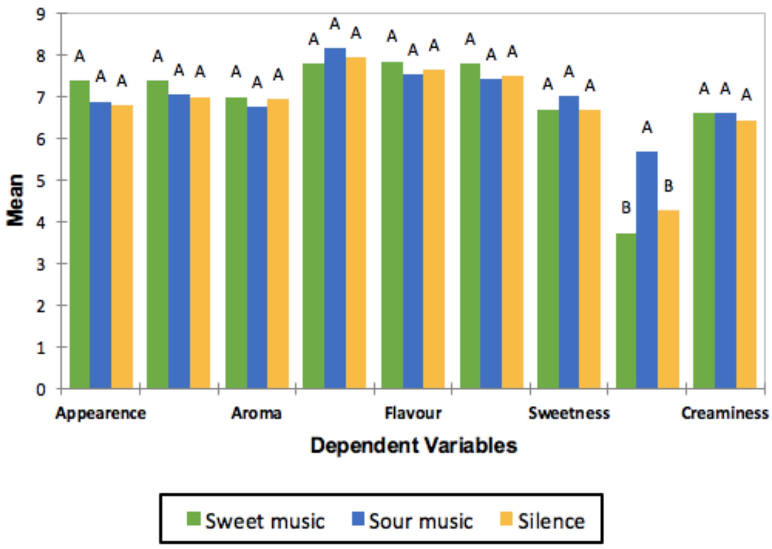


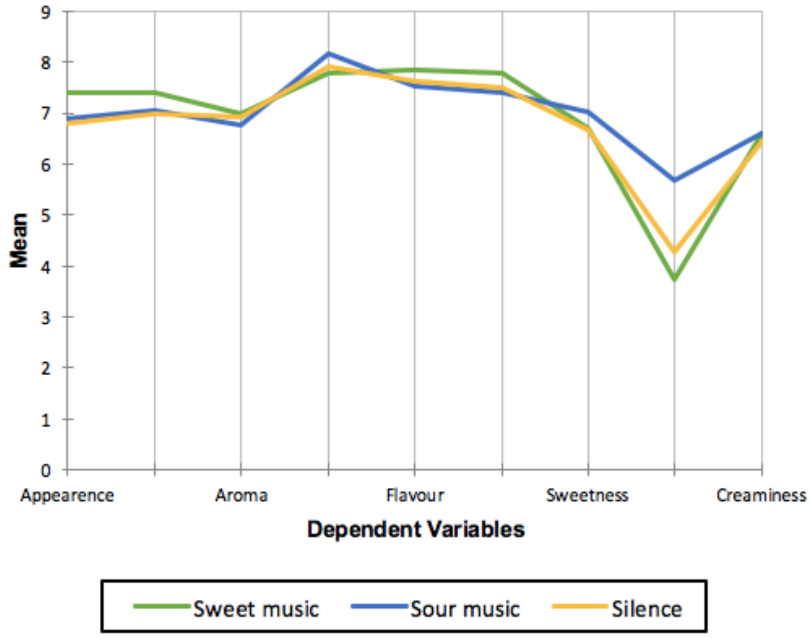
High Sweetness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,361	7,404	6,882	0,259
	Silence	6,211	7,361	6,786	0,286
	Sweet music	6,919	7,881	7,400	0,239
Colour	Sour music	6,524	7,594	7,059	0,266
	Silence	6,411	7,589	7,000	0,293
	Sweet music	6,907	7,893	7,400	0,245
Aroma	Sour music	6,104	7,425	6,765	0,328
	Silence	6,201	7,656	6,929	0,362
	Sweet music	6,391	7,609	7,000	0,303
Texture	Sour music	7,751	8,602	8,176	0,212
	Silence	7,459	8,398	7,929	0,233
	Sweet music	7,407	8,193	7,800	0,195
Flavour	Sour music	7,199	7,860	7,529	0,164
	Silence	7,279	8,007	7,643	0,181
	Sweet music	7,546	8,154	7,850	0,151
Overall experience	Sour music	7,034	7,790	7,412	0,188
	Silence	7,084	7,916	7,500	0,207
	Sweet music	7,452	8,148	7,800	0,173
Sweetness*	Sour music	6,664	7,395	7,029	0,182
	Silence	6,283	7,088	6,686	0,200
	Sweet music	6,368	7,042	6,705	0,168
Sourness*	Sour music	4,733	6,608	5,671	0,466
	Silence	3,231	5,297	4,264	0,514
	Sweet music	2,876	4,604	3,740	0,430
Creaminess*	Sour music	5,708	7,492	6,600	0,443
	Silence	5,460	7,425	6,443	0,489
	Sweet music	5,798	7,442	6,620	0,409

* The values are presented in centimetres (cm).

Impact of the three experiences on the mean perception of the attributes - High Sweetness



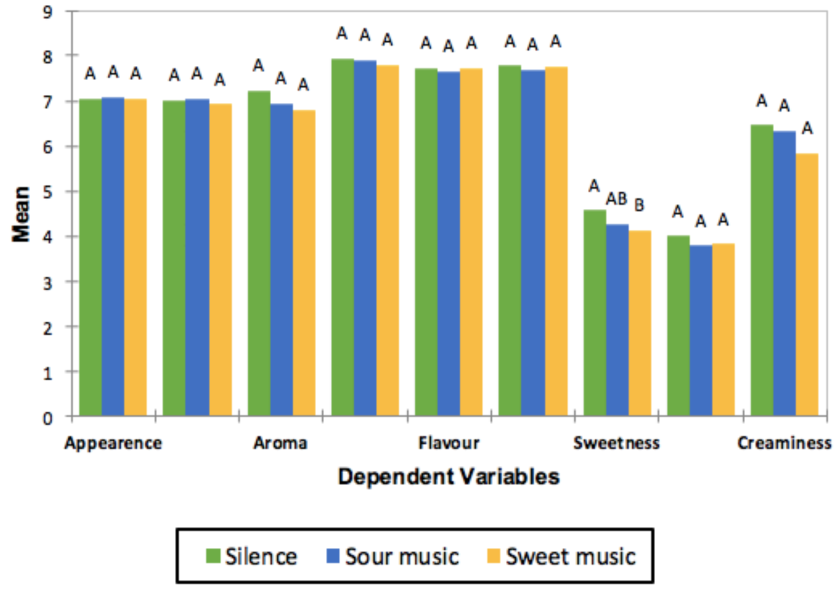


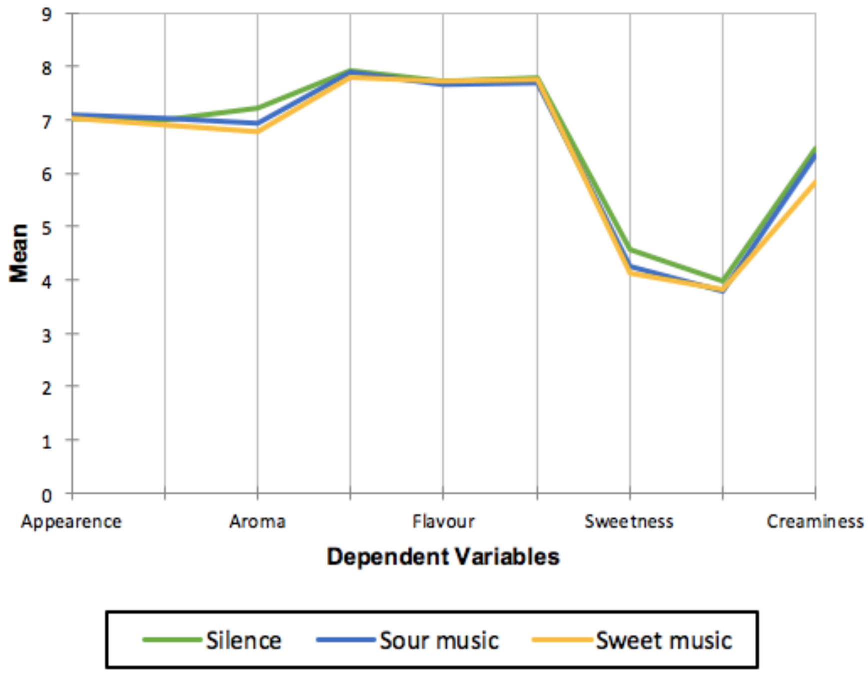
Medium Sweetness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,644	7,510	7,077	0,217
	Silence	6,636	7,428	7,032	0,199
	Sweet music	6,591	7,492	7,042	0,226
Colour	Sour music	6,617	7,460	7,038	0,212
	Silence	6,614	7,386	7,000	0,194
	Sweet music	6,478	7,355	6,917	0,220
Aroma	Sour music	6,453	7,393	6,923	0,236
	Silence	6,795	7,657	7,226	0,216
	Sweet music	6,302	7,281	6,792	0,246
Texture	Sour music	7,590	8,179	7,885	0,148
	Silence	7,665	8,206	7,935	0,136
	Sweet music	7,485	8,099	7,792	0,154
Flavour	Sour music	7,384	7,924	7,710	0,124
	Silence	7,463	7,957	7,710	0,124
	Sweet music	7,428	7,989	7,708	0,141
Overall experience	Sour music	7,437	7,948	7,774	0,118
	Silence	7,540	8,008	7,774	0,118
	Sweet music	7,484	8,016	7,750	0,134
Sweetness*	Sour music	3,967	4,525	4,246	0,140
	Silence	4,305	4,817	4,561	0,129
	Sweet music	3,838	4,420	4,129	0,146
Sourness*	Sour music	2,981	4,573	3,777	0,400
	Silence	3,261	4,719	3,990	0,366
	Sweet music	2,984	4,641	3,813	0,416
Creaminess*	Sour music	5,679	6,998	6,338	0,331
	Silence	5,851	7,059	6,455	0,303
	Sweet music	5,135	6,507	5,821	0,345

* The values are presented in centimetres (cm).

Impact of the three experiences on the mean perception of the attributes - Medium Sweetness





Low Sweetness

Attribute	Condition	Min	Max	Mean	Standard deviation
Appearance	Sour music	6,615	8,385	7,500	0,410
	Silence	6,666	8,834	7,750	0,502
	Sweet music	5,949	7,718	6,833	0,410
Colour	Sour music	6,946	8,721	7,833	0,411
	Silence	6,413	8,587	7,500	0,503
	Sweet music	5,779	7,554	6,667	0,411
Aroma	Sour music	6,741	8,593	7,667	0,429
	Silence	5,366	7,634	6,500	0,525
	Sweet music	5,074	6,926	6,000	0,429
Texture	Sour music	6,862	8,472	7,667	0,373
	Silence	7,014	8,986	8,000	0,456
	Sweet music	6,695	8,305	7,500	0,373
Flavour	Sour music	6,483	8,850	7,667	0,548
	Silence	5,800	8,700	7,250	0,671
	Sweet music	6,483	8,850	7,667	0,548
Overall experience	Sour music	6,550	8,783	7,667	0,517
	Silence	5,633	8,367	7,000	0,633
	Sweet music	6,383	8,617	7,500	0,517
Sweetness*	Sour music	1,918	2,482	2,200	0,131
	Silence	1,854	2,546	2,200	0,160
	Sweet music	1,851	2,416	2,133	0,131
Sourness*	Sour music	2,807	5,827	4,317	0,699
	Silence	3,276	6,974	5,125	0,856
	Sweet music	1,740	4,760	3,250	0,699
Creaminess*	Sour music	3,542	6,891	5,217	0,775
	Silence	3,299	7,401	5,350	0,949
	Sweet music	4,825	8,175	6,500	0,775

* The values are presented in centimetres (cm).

Impact of the three experiences on the mean perception of the attributes - Low Sweetness